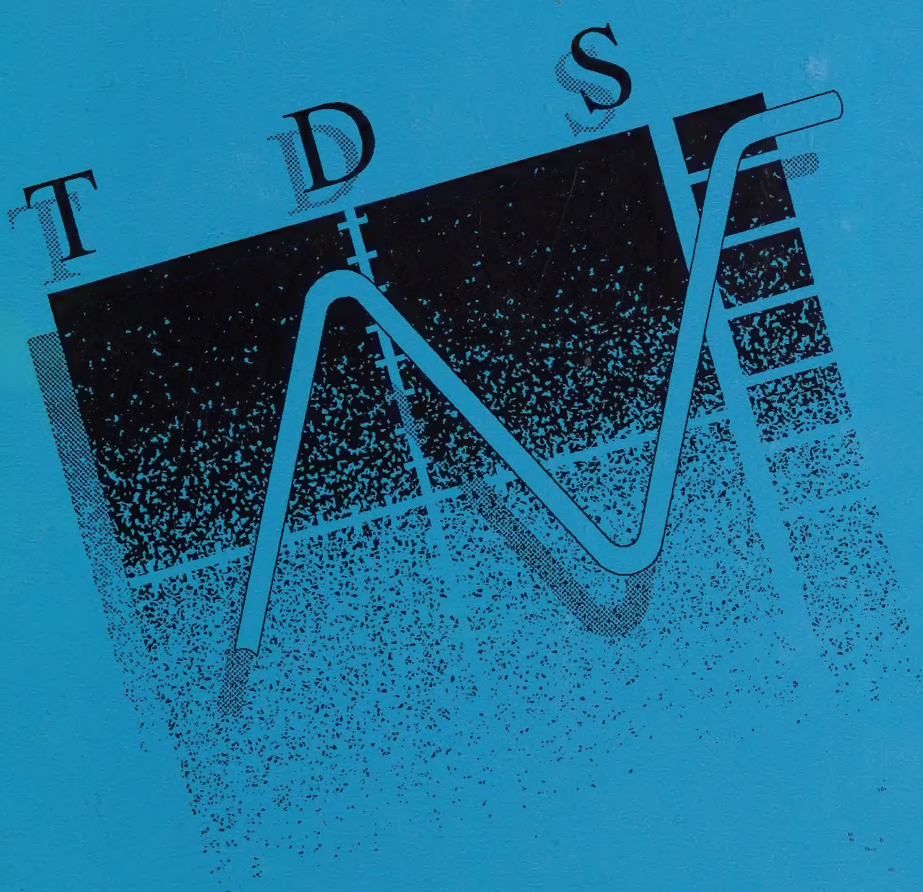
THE TDS 420 & TDS 460

DIGITIZING OSCILLOSCOPES



Tutorial/User Manual

TEK TDS 420
TEK TDS 460

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Part No. 070-8034-00
Product Group 3G

THE TDS 420 &TDS 460 DIGITIZING OSCILLOSCOPES

Tutorial/User Manual

Please check for CHANGE INFORMATION at the rear of this manual.

First Printing NOV 1991
REV JUN 1992

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E200000	Tektronix United Kingdom, Ltd., London
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Welcome

This is the Tutorial/User Manual for the TDS 420 and TDS 460 Digitizing Oscilloscopes.

If you are a new user, try the *Tutorial* section to become familiar with your digitizing oscilloscope's operation.

The *Concepts* section covers basic principles of the oscilloscope's operation. These articles help you understand why your instrument works the way it does.

Use the *In Detail* section to learn how to perform specific tasks.

The *Appendices* provide an option and accessories listing, product specifications, performance verification instructions, and other useful information.

Related Manuals

Other documentation for the digitizing oscilloscope includes:

- The TDS Family Programmer Manual (Tektronix part number 070-8318-01) describes using a computer to control the digitizing oscilloscope through the GPIB interface.
- The TDS Quick Reference (Tektronix part number 070-8035-00) gives you a quick overview of how to operate your digitizing oscilloscope.
- The TDS 420 Module Level Service Manual (Tektronix part number 070-8036-00) and the TDS 460 Module Level Service Manual (070-8037-00) provide information for maintaining and servicing your digitizing oscilloscope to the module level, including a description of the digitizing oscilloscope's operation.

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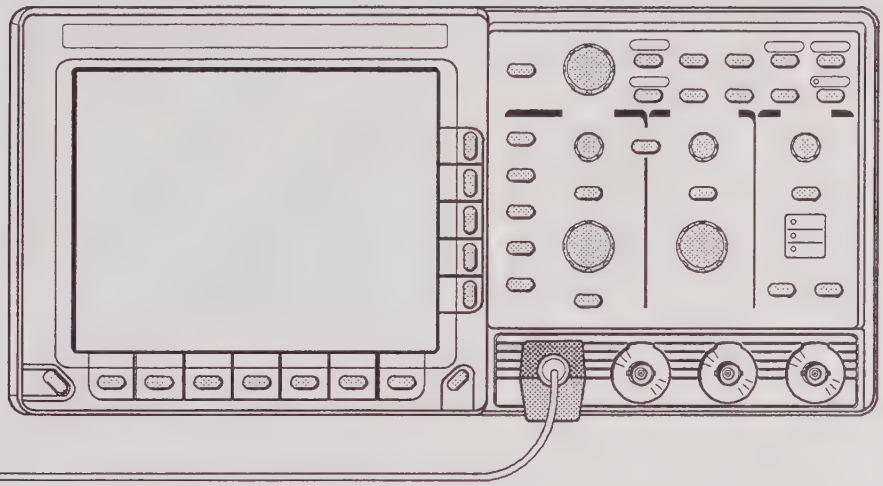
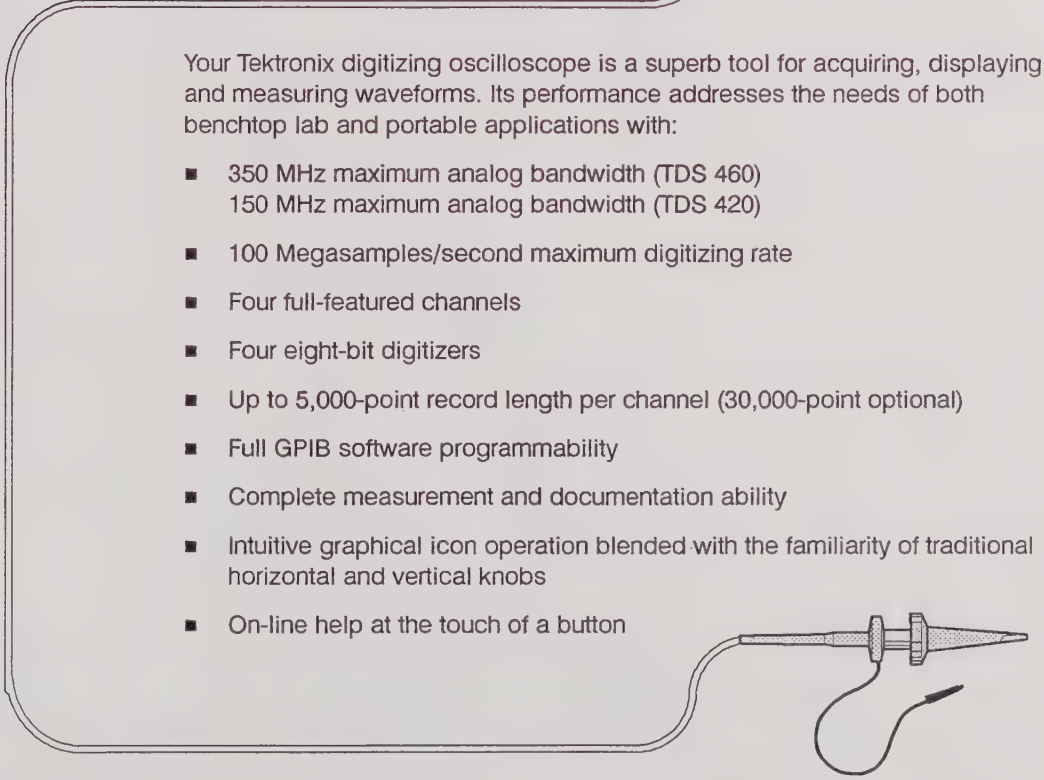
Product Description



Your Tektronix digitizing oscilloscope is a superb tool for acquiring, displaying, and measuring waveforms. Its performance addresses the needs of both benchtop lab and portable applications with:

- 350 MHz maximum analog bandwidth (TDS 460)
  150 MHz maximum analog bandwidth (TDS 420)
- 100 Megasamples/second maximum digitizing rate
- Four full-featured channels
- Four eight-bit digitizers
- Up to 5,000-point record length per channel (30,000-point optional)
- Full GPIB software programmability
- Complete measurement and documentation ability
- Intuitive graphical icon operation blended with the familiarity of traditional horizontal and vertical knobs
- On-line help at the touch of a button



Safety

Please take a moment to review these safety precautions. They are provided for your protection and to prevent damage to the digitizing oscilloscope. This safety information applies to all operators and service personnel.

Symbols and Terms

These two terms appear in manuals:

- CAUTION statements identify conditions or practices that could result in damage to the equipment or other property.
- WARNING statements identify conditions or practices that could result in personal injury or loss of life.

These two terms appear on equipment:

- *CAUTION* indicates a personal injury hazard not immediately accessible as one reads the marking, or a hazard to property including the equipment itself.
- *DANGER* indicates a personal injury hazard immediately accessible as one reads the marking.

This symbol appears in manuals:

Static-Sensitive Devices

These symbols appear on equipment:

DANGER
High Voltage

Protective
ground (earth)
terminal

ATTENTION
Refer to
manual

Specific Precautions

Observe all of these precautions to ensure your personal safety and to prevent damage to either the digitizing oscilloscope or equipment connected to it.

Power Source

The digitizing oscilloscope is intended to operate from a power source that will not apply more than 250 V rms between the supply conductors or between either supply conductor and ground. A protective ground connection, through the grounding conductor in the power cord, is essential for safe system operation.

Grounding the Digitizing Oscilloscope

The digitizing oscilloscope is grounded through the power cord. To avoid electric shock, plug the power cord into a properly wired receptacle where earth ground has been verified by a qualified service person. Do this before making connections to the input or output terminals of the digitizing oscilloscope.

Without the protective ground connection, all parts of the digitizing oscilloscope are potential shock hazards. This includes knobs and controls that may appear to be insulators.

Use the Proper Power Cord

Use only the power cord and connector specified for your product. Use only a power cord that is in good condition.

Use the Proper Fuse

To avoid fire hazard, use only the fuse specified in the parts list for your product, matched by type, voltage rating, and current rating.

Do Not Remove Covers or Panels

To avoid personal injury, do not operate the digitizing oscilloscope without the panels or covers.

Do Not Operate in Explosive Atmospheres

The digitizing oscilloscope provides no explosion protection from static discharges or arcing components. Do not operate the digitizing oscilloscope in an atmosphere of explosive gases.

Electric Overload

Never apply to a connector on the digitizing oscilloscope a voltage that is outside the range specified for that connector.

Start Up

Before you use the digitizing oscilloscope, ensure that it is properly installed and powered on.

Operation

To install and power on the digitizing oscilloscope, do the following:

Installation

☐ **Step 1:** Be sure you have the appropriate operating environment. Specifications for temperature, relative humidity, altitude, vibrations, and emissions are included in *Appendix B: Specification* at the rear of this manual.

☐ **Step 2:** Leave space for cooling. Do this by verifying that the air intake and exhaust holes on the sides of the cabinet (where the fan operates) are free of any airflow obstructions. Leave at least 2 inches (5.1 cm) free on each side.

WARNING

To avoid electrical shock, be sure that the power cord is disconnected before checking the fuse.

☐ **Step 3:** Check the fuse to be sure it is the proper type and rating (Figure i). You can use either of two fuses. Each fuse requires its own cap (see Table i). The digitizing oscilloscope is shipped with the UL approved fuse installed.

☐ **Step 4:** Check that you have the proper electrical connections. The digitizing oscilloscope requires 90 to 132 V for 48 through 62 Hz, 100 to 132 V or 180 to 250 V for 48 through 440 Hz, and may require up to 240 W.

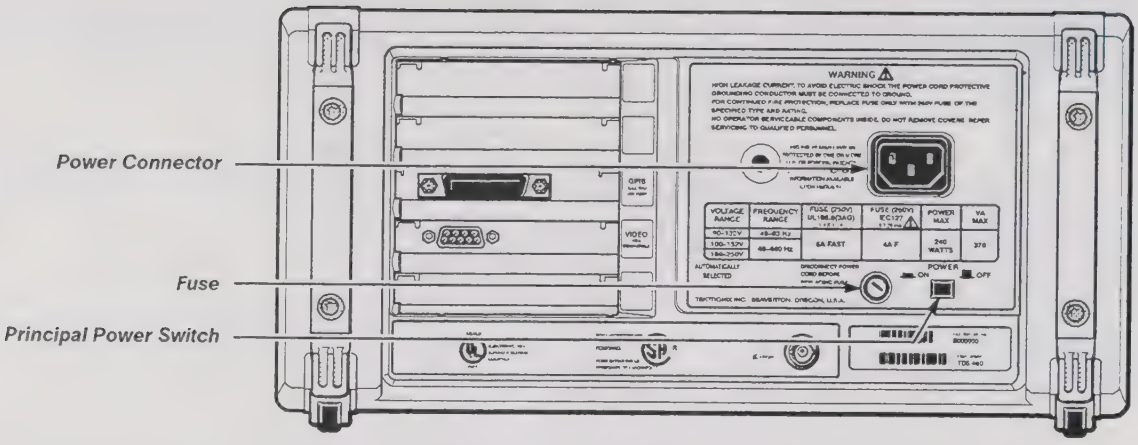


Figure i: Rear Panel Controls Used in Start Up

Table i: Fuse and Fuse Cap Part Numbers

Fuse	Fuse Part Number	Fuse Cap Part Number
.25 inch × 1.25 inch (UL 198.6, 3AG): 5 A FAST, 250 V.	159-0906-00	200-2264-00
5 mm × 20 mm (IEC 127): 4 A (T), 250 V.	159-0255-00	200-2265-00

☐ **Step 5:** Connect the proper power cord from the rear-panel power connector (Figure i) to the power system.

Power On

☐ **Step 6:** Check that the rear-panel principal power switch is on (Figure i). The principal power switch controls all AC power to the instrument.

☐ **Step 7:** If the oscilloscope isn't powered on (the screen is blank), check that the front-panel **ON/STBY** button is toggled on (Figure ii).

The **ON/STBY** button controls power to most of the instrument's circuits. Power continues to go to certain parts even when this switch is set to STBY.

Once the digitizing oscilloscope is installed, it is typical to leave the principal power switch on and use the **ON/STBY** button as the power switch.

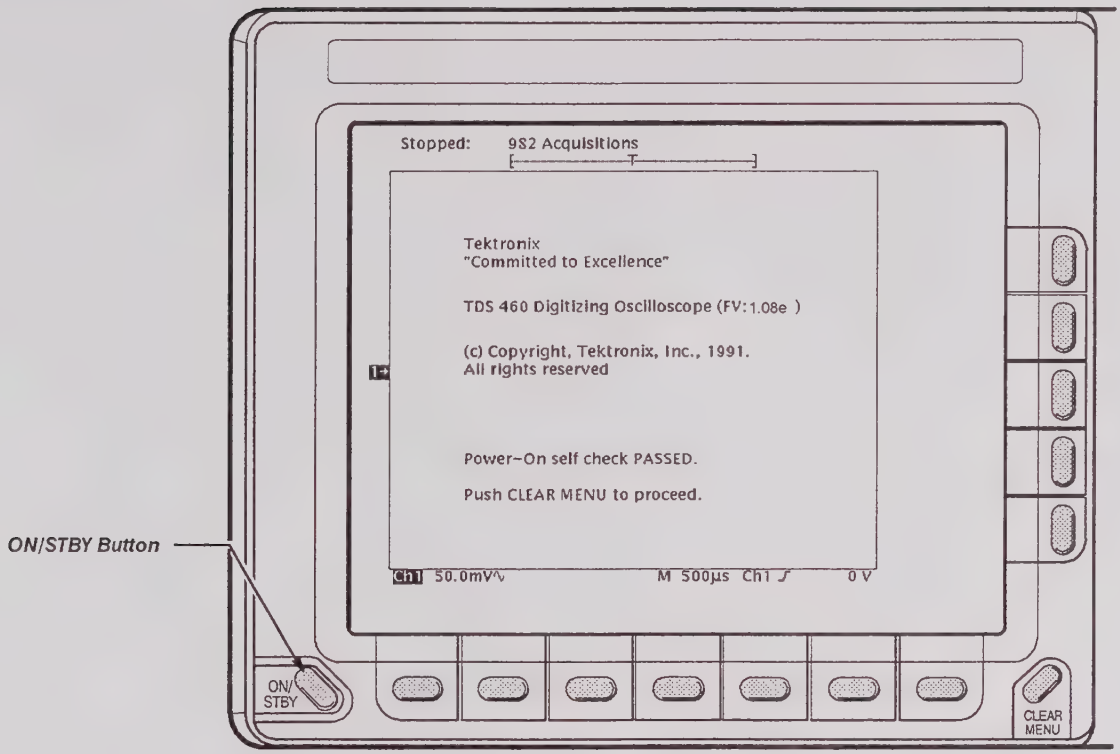


Figure ii: ON/STBY Button

Self Test

☐ **Step 8:** Check the self test results. The digitizing oscilloscope automatically performs power-up tests each time it is turned on. It will come up with a display screen that states whether or not it passed self test.

If the self test fails, call your local Tektronix Service Center. Depending on the type of failure, you may still be able to use the oscilloscope in the interim.

Power Off

☐ **Step 9:** Toggle the **ON/STBY** switch.

Tutorial

Replace this page with the tab divider of the same name.

Overview

This section presents four examples discussing the digitizing oscilloscope's basic functions. Use the *At A Glance* section (starting on page 3-3) to help you locate the correct knobs, buttons, and menus.

- *Example 1* teaches you how to reset the digitizing oscilloscope, display and adjust waveforms, and use the autoset function.
- *Example 2* explains how to add, control, and delete multiple waveforms.
- *Example 3* introduces you to the automated measurement system.
- *Example 4* discusses saving and recalling the digitizing oscilloscope's setups.

If you don't perform the examples, use the *Concepts* and *In Detail* sections to learn about the digitizing oscilloscope's arrangement and specific functions.

Setting Up for the Examples

All the examples use the same setup. Once you perform this setup, you don't have to change the signal connections for any of the other examples.

Remove all probes and signal inputs from the input BNC connectors along the lower right of the front panel. Then, using one of the probes supplied with the digitizing oscilloscope, connect from the **CH 1** connector to the **PROBE COMP** connectors (Figure 1-1).

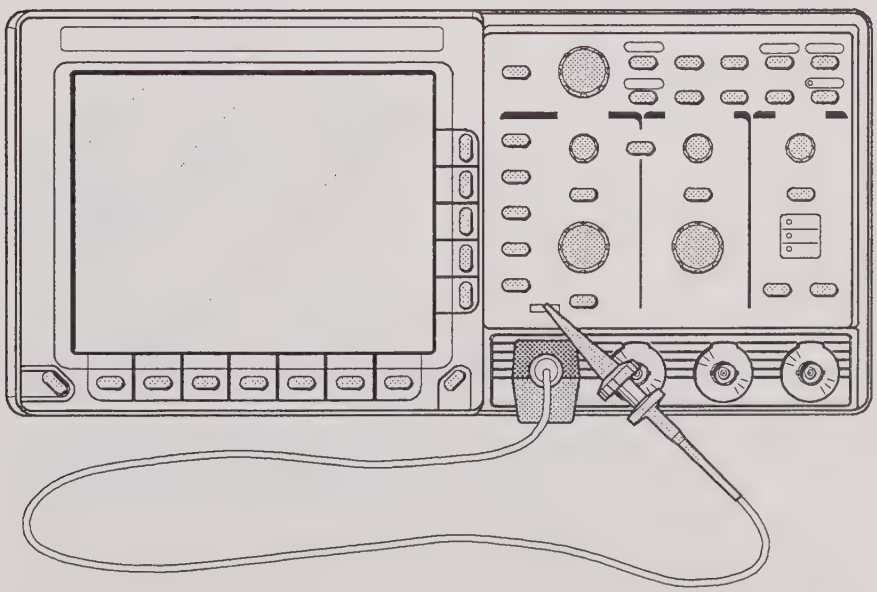


Figure 1-1: Connecting a Probe for the Examples

Example 1: Displaying a Waveform

In this first example you learn about resetting the digitizing oscilloscope, displaying and adjusting a waveform, and using the autoset function.

Resetting the Digitizing Oscilloscope

All examples in the tutorial begin by resetting the digitizing oscilloscope to a known, factory default state. That is useful when you begin a new task and need to "start fresh" with known default settings.

☐ **Step 1:** Press the save/recall **SETUP** button to display the Setup menu (Figure 1-2).

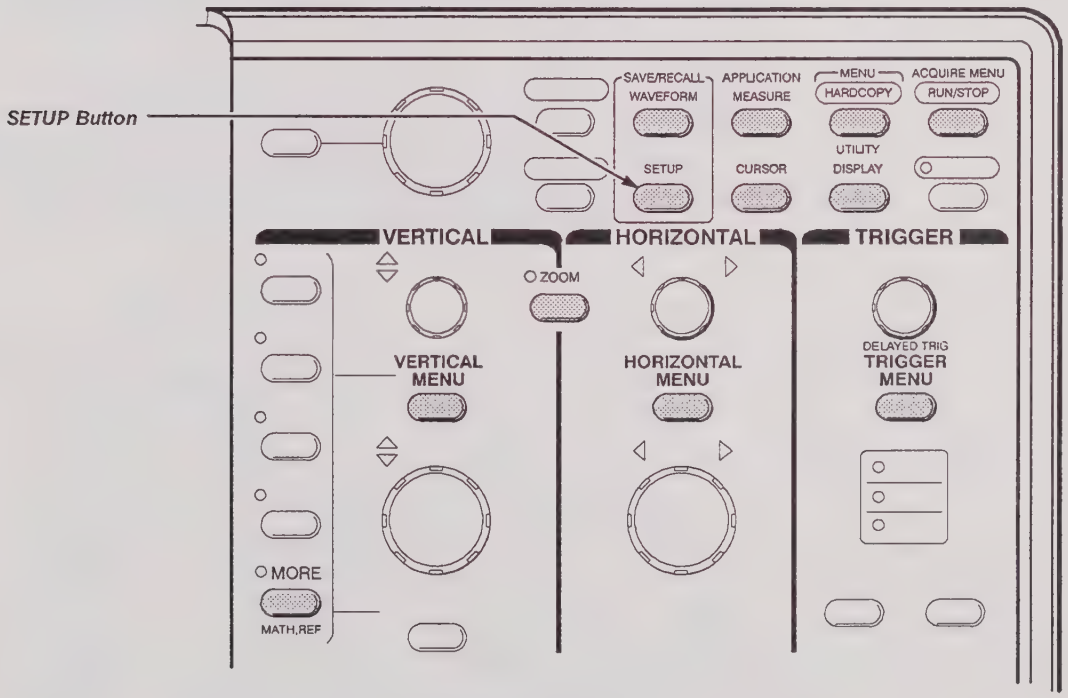


Figure 1-2: Menu Button Locations (Gray Buttons)

The digitizing oscilloscope displays main menus along the bottom of the screen. Figure 1-3 shows the Setup main menu.

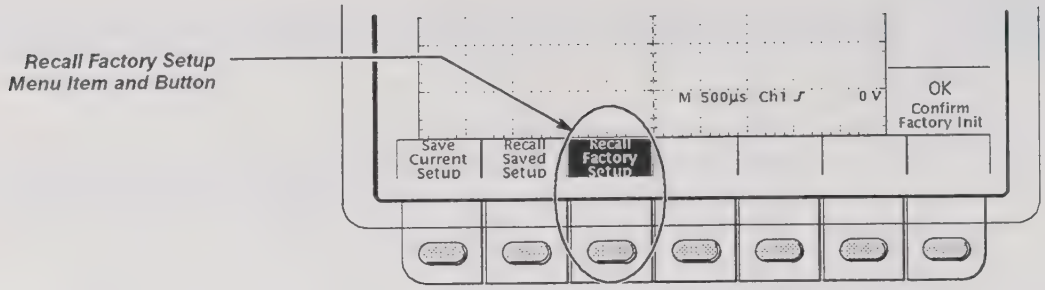


Figure 1-3: The Displayed Setup Menu

To select menu items from a displayed main menu, you press the button below the desired menu item. For example, the third menu item from the left is **Recall Factory Setup**, which is what you want.

☐ **Step 2:** Press the button directly below the **Recall Factory Setup** menu item.

The display shows side menus along the right side of the screen. The buttons to select these side menu items are to the right of the screen.

Because an accidental instrument reset could destroy a setup that took a long time to create, the digitizing oscilloscope asks you to verify the **Recall Factory Setup** main menu selection (see Figure 1-4).

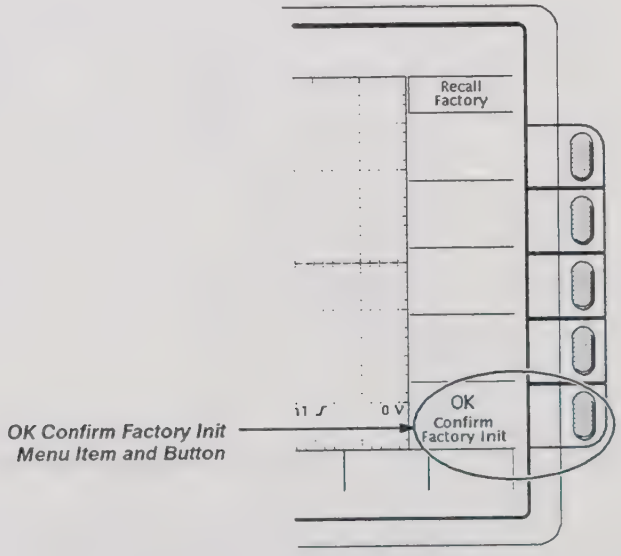


Figure 1-4: The Recall Factory Side Menu

☐ **Step 3:** Press the button to the right of the **OK Confirm Factory Init** side menu item.

☐ **Step 4:** Press the **SET LEVEL TO 50%** button (see Figure 1-5) to be sure the oscilloscope triggers on the input signal.

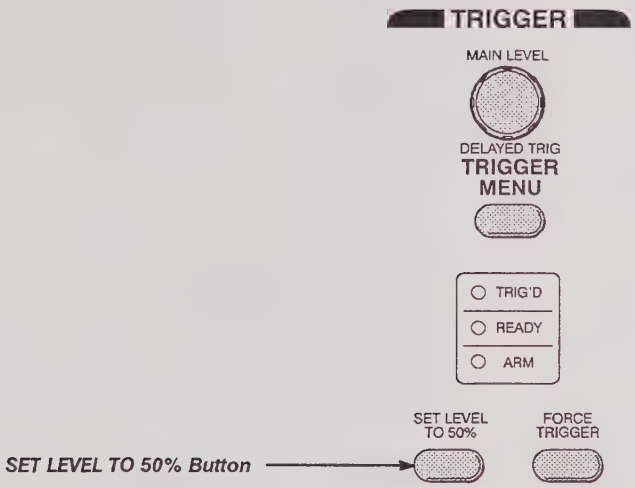


Figure 1-5: SET LEVEL TO 50% Button

Display Elements

Figure 1-6 shows the display that results from the instrument reset.

There are several important points to observe:

- The trigger position indicator shows the waveform's trigger position being in the horizontal center of the graticule.
- The channel ground reference indicator shows the vertical position of channel 1 ground.
- The trigger readout shows that the digitizing oscilloscope is triggering on channel 1 (**Ch1**) on a rising edge, and that the trigger level is 300 mV.
- The time base readout shows that the main time base is showing a horizontal scale of 500 µs/div.
- The channel readout indicates that channel 1 (**Ch1**) is being displayed with DC coupling (in AC coupling, a ~ appears after the volts/div readout). The digitizing oscilloscope always displays channel 1 at reset.

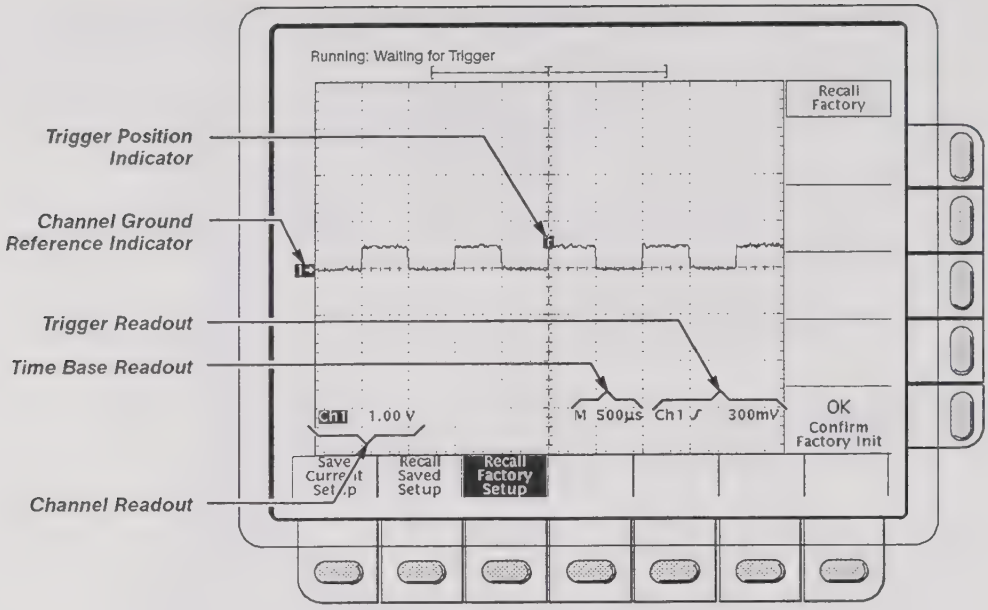


Figure 1-6: The Display After Factory Initialization

Right now, the channel, time base, and trigger readouts appear in the graticule area. You can always press the **CLEAR MENU** button to remove any menus and to move the readouts below the graticule.

Adjusting the Waveform Display

The display shows the probe compensation signal. It is a 1 kHz square wave of approximately 0.5 V amplitude. You can adjust the size and placement of the waveform using the front-panel knobs.

Figure 1-7 shows the main **VERTICAL** and **HORIZONTAL** sections of the front panel. Each has **SCALE** and **POSITION** knobs.

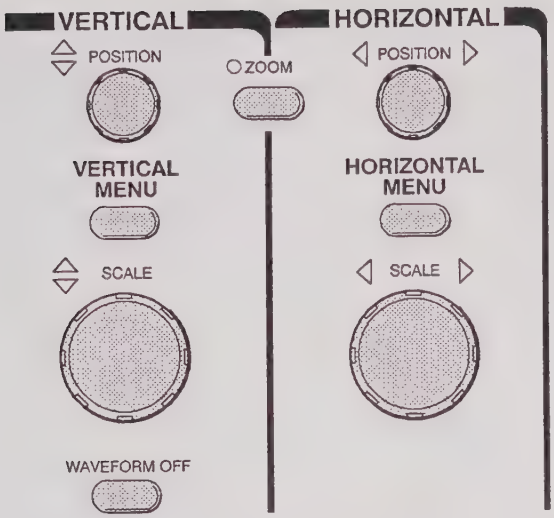


Figure 1-7: The VERTICAL and HORIZONTAL Controls

☐ **Step 5:** Turn the vertical **SCALE** knob clockwise and observe the change in the displayed waveform and the channel readout at the bottom of the display.

☐ **Step 6:** Turn the vertical **POSITION** knob first one direction, then the other. Observe the change in the displayed waveform. Then return the waveform to the center of the graticule.

☐ **Step 7:** Turn the horizontal **SCALE** knob one click clockwise. Observe the time base readout at the bottom of the display. The time base should be set to 200 µs/div now, and you should see two complete waveform cycles on the display.

Using Autoset

When you first connect a signal to a channel and display it, the signal displayed may not be useable. Use the digitizing oscilloscope's autoset function when that happens and you will quickly get a meaningful display.

When you reset the digitizing oscilloscope, you saw a clear, stable display of the probe compensation waveform. That is because the probe compensation signal happens to match the default settings of the digitizing oscilloscope.

☐ **Step 8:** To create an unstable display, slowly turn the trigger **MAIN LEVEL** knob (see Figure 1-8) first one direction, then the other. Observe what happens when you move the trigger level above the highest part of the displayed waveform. Leave the trigger level in that untriggered state.

Figure 1-8: TRIGGER Controls

Now use the **AUTOSET** button to quickly get a clear, stable display.

☐ **Step 9:** Press the **AUTOSET** button (see Figure 1-9) and observe the stable waveform display.

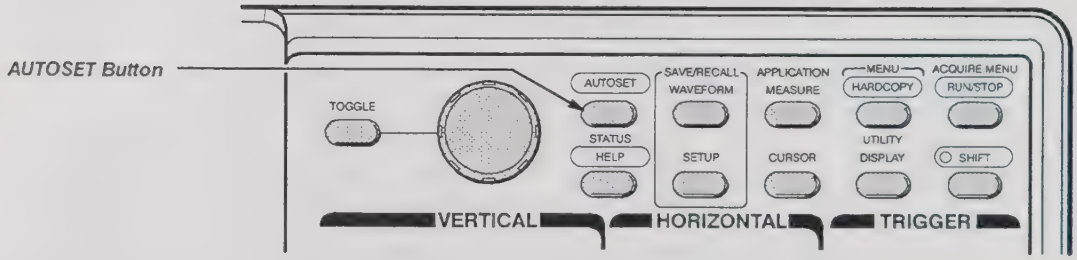


Figure 1-9: AUTOSET Button Location

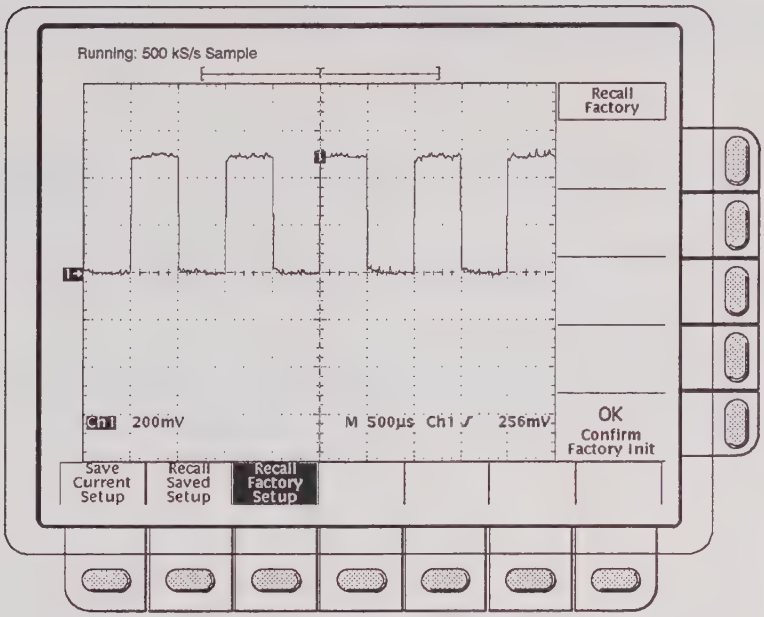


Figure 1-10: The Display After Pressing Autoset

Figure 1-10 shows the display after pressing **AUTOSET**. If necessary, you can adjust the waveform now by using the knobs discussed earlier in this example.

NOTE

If the corners on your displayed signal look rounded or pointed (see Figure 1-11), then you may need to compensate your probe. The section called Probe Compensation *on page 3-79 explains how to do that.*

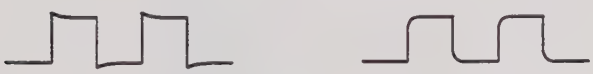


Figure 1-11: Display Signals Requiring Probe Compensation

Example 2: Multiple Waveforms

In this example you learn how to display and control more than one waveform at a time.

- ☐ **Step 1:** If you aren't continuing from the previous example, follow the instructions on page 1-1 under the heading "Setting Up for the Examples."
- ☐ **Step 2:** Reset the digitizing oscilloscope. (Press the **SETUP** button, and on the main menu press the **Recall Factory Setup** button. Then, on the side menu, press the **OK Confirm Factory Init** button and finally press the **SET LEVEL TO 50%** button.)
- ☐ **Step 3:** Press the **AUTOSET** button.

Adding a Waveform

The **VERTICAL** section of the front panel contains the channel selection buttons. These are **CH 1**, **CH 2**, **CH 3**, **CH 4**, and **MORE** (Figure 1-12).

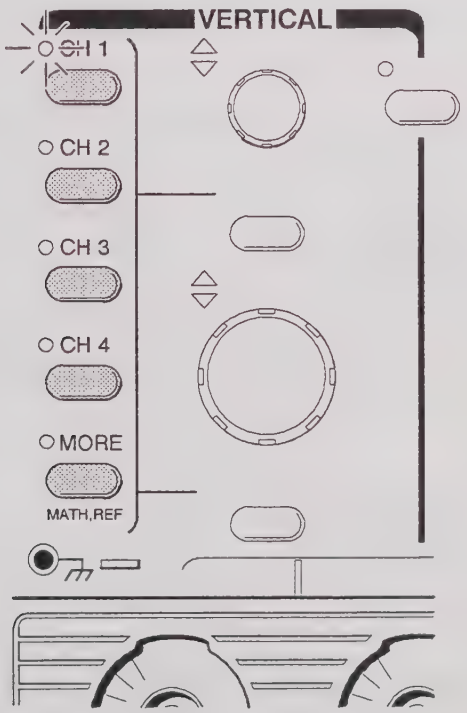


Figure 1-12: The Channel Buttons and Lights

Each of the channel (**CH**) buttons has a light beside its label. Right now, the **CH 1** light is on. That indicates that the vertical controls are set to adjust channel 1.

☐ **Step 4:** Press the **CH 2** button.

The display shows a second waveform, which represents the signal on channel 2. Since there is nothing connected to the **CH 2** input connector, this waveform is a flat line.

There are several other important things to observe:

- The channel readout on the display now shows the settings for both **Ch1** and **Ch2**.
- There are two channel indicators at the left edge of the graticule. Right now, they overlap.
- The light next to the **CH 2** button is now on, and the **CH 1** light is off. Because the knobs control only one channel at a time, the vertical controls are now set to adjust channel 2.
- The trigger readout still indicates that the trigger is detecting trigger events on **Ch1**. This has not changed by your adding a channel. (You can change the trigger source by using the **TRIGGER MENU** button to display the trigger menu.)

☐ **Step 5:** Turn the vertical **POSITION** knob clockwise to move the channel 2 waveform up on the graticule. You will notice that the channel ground reference indicator for channel 2 moves with the waveform.

☐ **Step 6:** Press the **VERTICAL MENU** button.

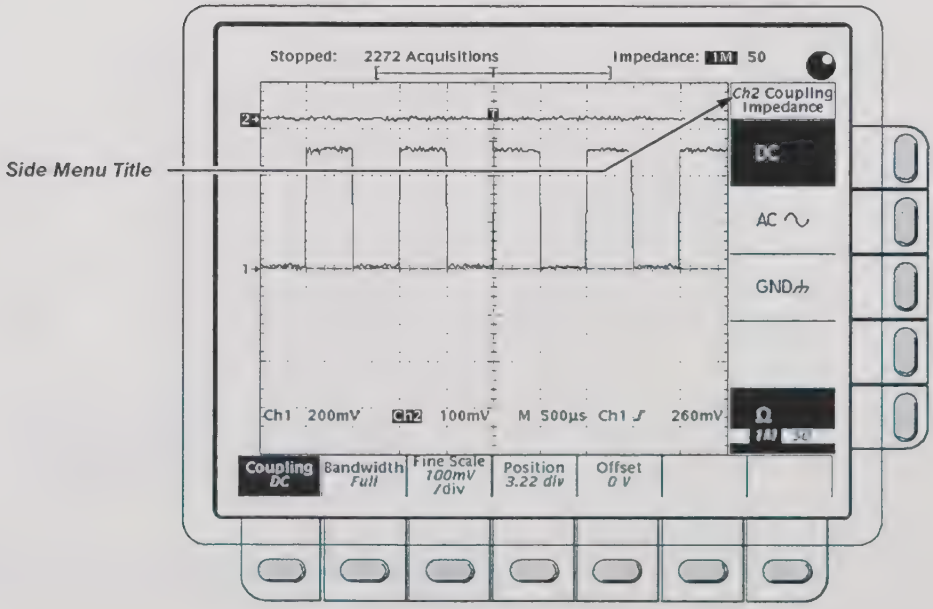


Figure 1-13: The Vertical Main Menu and Coupling Side Menu

The **VERTICAL MENU** button displays a menu that gives you control over many vertical channel parameters (Figure 1-13). Although there can be more than one channel displayed, the vertical menu and buttons only adjust the selected channel.

Each menu item in the Vertical menu displays a side menu. Right now, the **Coupling** item in the main menu is highlighted, which means that the side menu shows the coupling choices. At the top of the side menu, the menu title shows the channel affected by the menu choices. That always matches the lighted channel button.

☐ **Step 7:** Press the side menu button for Ω to toggle the selection to **50** Ω. That changes the input coupling of channel 2 from 1 MΩ to 50 Ω. Observe that the channel readout for channel 2 (near the bottom of the graticule) shows an Ω indicator now.

Changing Controls to Another Channel

Pressing a channel (**CH**) button sets the vertical controls to that channel. It also adds the channel to the display if that waveform is not already displayed.

☐ **Step 8:** Press the **CH 1** button in the vertical section of the front panel.

Observe that now the side menu title shows **Ch1**, and that the light next to **CH 1** is lighted (Figure 1-14). The highlighted menu item in the side menu has changed from the **50** Ω channel 2 setting to the **1 M**Ω impedance setting of channel 1.

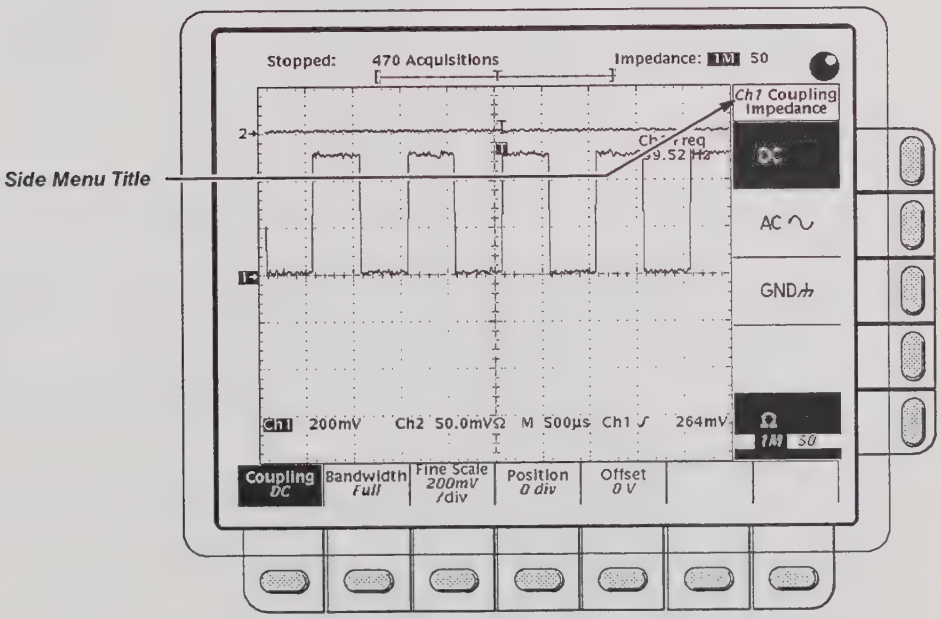


Figure 1-14: The Menus After Changing Channels

You now need to return the coupling impedance of channel 2 to 1 MΩ.

☐ **Step 9:** Press the **CH 2** button.

☐ **Step 10:** Press the side menu button for Ω to toggle the selection to **1 MΩ**.

Removing a Waveform

You use a two-step process to remove waveforms from the display. First, select the channel using the channel (**CH**) button. Second, press the **WAVEFORM OFF** button.

☐ **Step 11:** Press the **WAVEFORM OFF** button (see Figure 1-15).

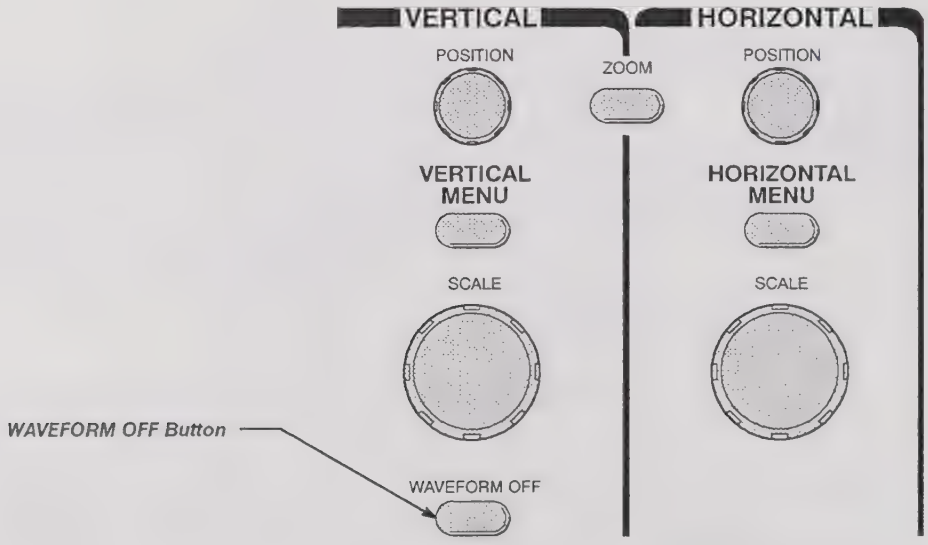


Figure 1-15: WAVEFORM OFF Button Location

Since the **CH 2** light was on when you pressed the **WAVEFORM OFF** button, the channel 2 waveform was removed.

The channel (**CH**) lights now indicate channel 1. Channel 1 has become the selected channel. When you remove the last waveform, all the **CH** lights are turned off.

☐ **Step 12:** Press the **WAVEFORM OFF** button again to remove the waveform from channel 1.

Example 3: Automated Measurements

In this example you learn how to use the automated measurement system to get numeric readouts of important waveform characteristics.

☐ **Step 1:** If you aren't continuing from the previous example, follow the instructions on page 1-1 under the heading "Setting Up for the Examples."

☐ **Step 2:** Reset the digitizing oscilloscope. (Press the **SETUP** button, and on the main menu press the **Recall Factory Setup** button. Then, on the side menu, press the **OK Confirm Factory Init** button and finally press the **SET LEVEL TO 50%** button.)

☐ **Step 3:** Press the **AUTOSET** button.

Displaying Automated Measurements

To use the automated measurement system, you must have a stable display of your signal. Also the waveform must have all the segments necessary for the measurement you want. For example, a rise time measurement requires at least one rising edge and a frequency measurement needs at least one cycle.

☐ **Step 4:** Press the **MEASURE** button to display the Measure main menu (see Figure 1-16).

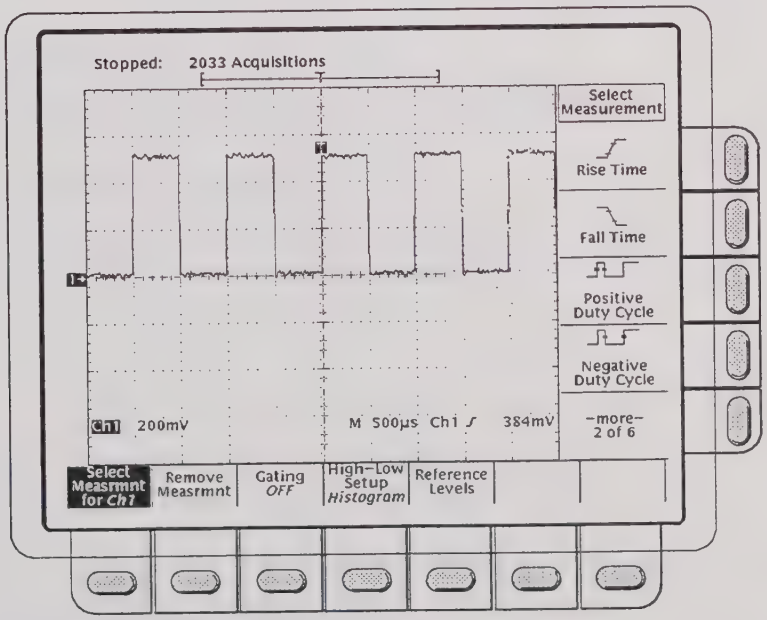


Figure 1-16: Measure Main Menu and Select Measurement Side Menu

☐ **Step 5:** If it is not already selected, press the button for the **Select Measrmnt** menu item. The readout for that menu item indicates which channel the measurement will be taken from. All automated measurements are made on the selected channel.

The right side of the display shows the Select Measurement side menu. That menu lists some of the measurements that can be taken on the waveform.

There are many different measurements available. You can select up to four measurements to be taken and displayed at any one time. Pressing the button next to the **–more–** menu item brings up the other measurement selections.

☐ **Step 6:** Press the **Frequency** button from the side menu. If the **Frequency** menu item is not visible, press the **–more–** button repeatedly until the **Frequency** item appears, then press the **Frequency** menu button.

Observe that the frequency measurement appears within the right side of the graticule area. The measurement readout includes the notation **Ch1**, meaning that that measurement is taken on the channel 1 waveform. (To take a measurement on another channel, you would select that channel, then select the measurement.)

☐ **Step 7:** Press the **Positive Width** side menu button.

☐ **Step 8:** Press the **–more–** side menu button once, and then press the **Rise time** and **Positive Duty Cycle** side menu buttons.

Observe that all four measurements are displayed. Right now, they cover a part of the graticule area, including the displayed waveforms. You can move the measurement readouts outside the graticule by pressing the **CLEAR MENU** button.

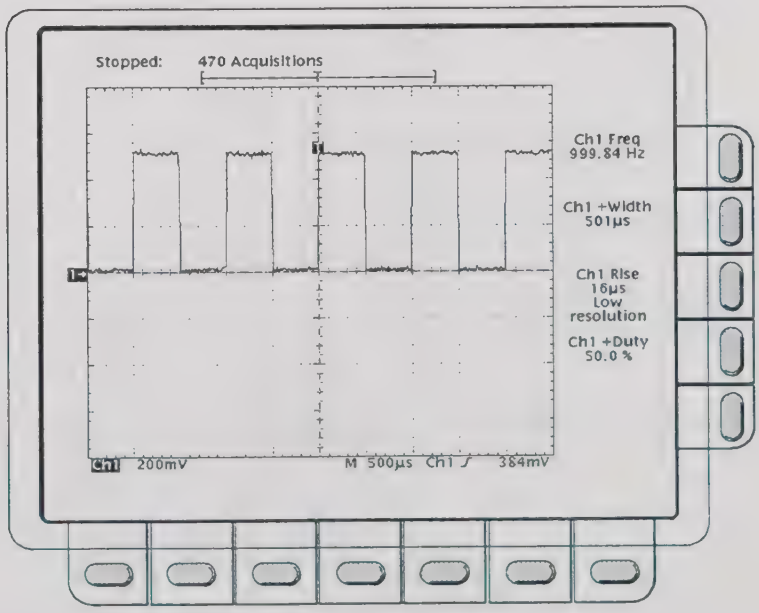


Figure 1-17: Four Simultaneous Measurement Readouts

☐ **Step 9:** Press the **CLEAR MENU** button.

The measurement readouts move to the right of the graticule, into the space formerly occupied by the side menu (Figure 1-17).

Removing Measurement Readouts

The Measure menu lets you remove measurements you no longer want displayed. You can remove any one measurement, or you can remove them all with a single menu item.

☐ **Step 10:** Press the **MEASURE** button again to display the Measure main menu.

☐ **Step 11:** Press the **Remove Measrmnt** main menu button to display the Remove Measurement side menu.

☐ **Step 12:** Press the **Measurement 1**, **Measurement 2**, and **Measurement 4** side menu buttons to remove those measurements. Leave the rise time measurement displayed.

If you want to remove all the measurements, press the **All Measurements** side menu button.

Changing the Measurement Reference Levels

By default, the measurement system will use the 10% and 90% levels of the waveform for taking the rise time measurement. You can change these values to other percentages, or change them to absolute voltage levels.

☐ **Step 13:** On the Measure main menu, press the **Reference Levels** button.

☐ **Step 14:** On the side menu, press the **High Ref** button.

The General Purpose Knob

The general purpose knob, the large knob in the upper left-hand corner next to the display, is now set to adjust the high reference level (Figure 1-18).

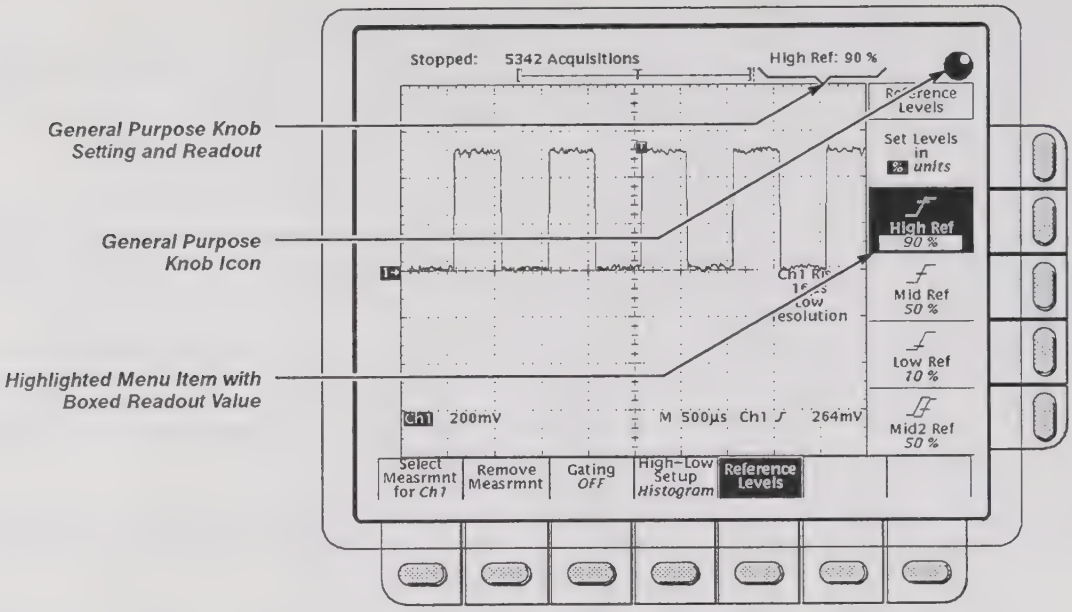


Figure 1-18: General Purpose Knob Indicators

There are several important things to observe on the screen:

- The knob icon appears at the top of the screen. That indicates that the general purpose knob has just been set to adjust a parameter.
- The upper right corner of the screen shows the readout **High Ref: 90%**.
- The **High Ref** side menu item is highlighted, and a box has been drawn around the 90% readout in the **High Ref** menu item. The box indicates that the general purpose knob is currently set to adjust that parameter.

☐ **Step 15:** Turn the general purpose knob left and right, and then use it to adjust the high level to 80%.

That sets the high measurement reference to 80%.

☐ **Step 16:** On the side menu, press the **Low Ref** button.

☐ **Step 17:** Using the general purpose knob adjust the low level to 20%.

That sets the low measurement reference to 20%.

Now you want to return the display to its original state.

☐ **Step 18:** Press the main menu's **Remove Measrmnt** button.

☐ **Step 19:** On the side menu, press the **All Measurements** button.

Example 4: Saving Setups

This example shows you how to save all the settings of the digitizing oscilloscope and how to recall the setup later to quickly re-establish the previously saved state. The oscilloscope provides several storage locations where you can save the setups.

Besides being able to save several complete setups, the digitizing oscilloscope remembers all the parameter settings when you power off. That feature lets you power on and continue where you left off without having to reconstruct the state of the digitizing oscilloscope.

- ☐ **Step 1:** If you aren't continuing from the previous example, follow the instructions on page 1-1 under the heading "Setting Up for the Examples."
- ☐ **Step 2:** Reset the digitizing oscilloscope. (Press the **SETUP** button, and on the main menu press the **Recall Factory Setup** button. Then, on the side menu, press the **OK Confirm Factory Init** button and finally press the **SET LEVEL TO 50%** button.)
- ☐ **Step 3:** Press the **AUTOSET** button.

Saving a Setup

First, you need to create an instrument setup you want to save. The next several steps establish a two-waveform display with a measurement on one waveform. That setup is complex enough that you would prefer not to go through all these steps each time you want that display.

- ☐ **Step 4:** Press the **MEASURE** button, then press **Select Measrmnt** in the main menu and press the **Frequency** side menu button. (Press the **--more--** button if the **Frequency** selection does not appear in the side menu.)
- ☐ **Step 5:** Press the **CH 2** button in the vertical section of the front panel.
- ☐ **Step 6:** Press the **CLEAR MENU** button.

Once you have established an instrument setup, you can save it in any of several setup locations.

NOTE

The next step asks you to save a setup in a setup location of your choice. If you work in a laboratory environment where several people share the digitizing oscilloscope, check with the other users to be certain the setup location you are using is not already being used by someone else.

☐ **Step 7:** Press the **SETUP** button to display the Setup main menu (see Figure 1-19). Press the **Save Current Setup** main menu button.

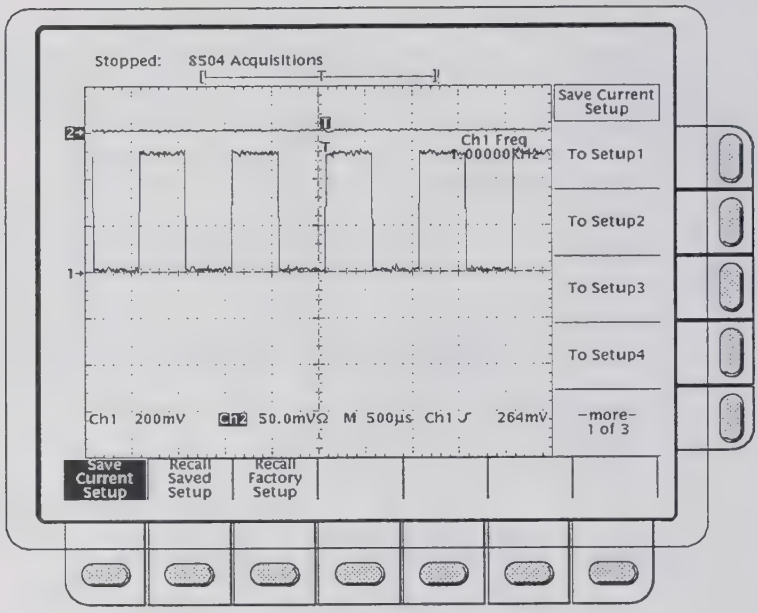


Figure 1-19: Save/Recall Setup Menu

☐ **Step 8:** Then, press one of the **To Setup** side menu buttons to store the current instrument settings into that setup location.

There are more setup locations than can be listed at one time in the side menu. The **–more–** side menu item gives you access to all the setup locations.

Once you have saved a particular setup, you can change the settings as you wish, knowing that you can come back to that setup at any time.

☐ **Step 9:** Press the **MEASURE** button to display the Measure main menu. Select the **Positive Width** side menu item to add that measurement to the display.

Recalling a Setup

☐ **Step 10:** Press the **SETUP** button to display the Setup main menu.

☐ **Step 11:** Press the **Recall Saved Setup** main menu button to display the Recall Setup side menu.

☐ **Step 12:** Press the **Recall Setup** side menu button for the setup location you used in Step 8. The oscilloscope returns to the setup you saved in Step 8. The positive width measurement is now removed from the display because you selected it after you saved the setup.

Concepts

Replace this page with the tab divider of the same name.

Overview

Understanding the basic concepts of your digitizing oscilloscope will help you use it much more effectively. This section explains the following concepts:

- the **triggering** system, which establishes conditions for acquiring signals. Properly set, triggers can convert displays from unstable jumbles or blank screens into meaningful waveforms (Figure 2-1). See page 2-5.

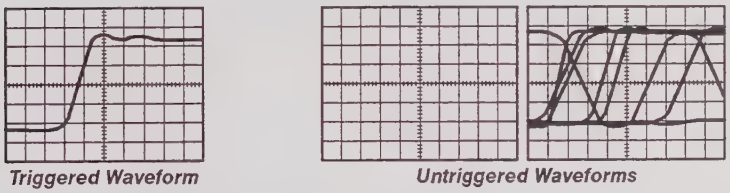


Figure 2-1: Examples of Triggered Waveforms

- the **acquisition** system, which lets you select the modes for converting analog data into digital form (Figure 2-2). See page 2-13.

Figure 2-2: Acquisition: Input Analog Signal, Sample, and Digitize

- the **waveform scaling and positioning** system, which changes the dimensions of the waveform display. Scaling waveforms involves increasing or decreasing their displayed size (Figure 2-3). Positioning means moving them up, down, right, and left on the display. See page 2-21.

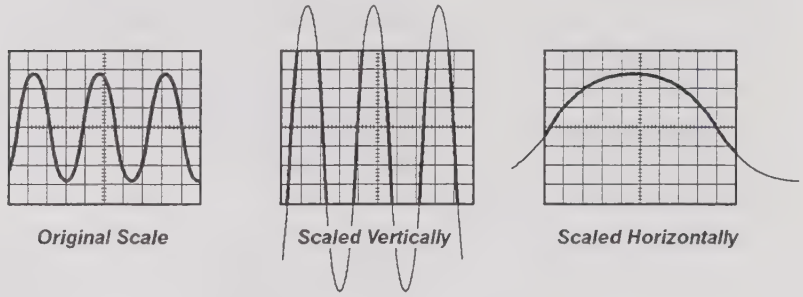


Figure 2-3: Examples of Scaling

- the **measurement** system, which provides numeric information on the displayed waveforms. Three measurement classes are supported: graticule, cursor and automated (Figure 2-4). See page 2-25.

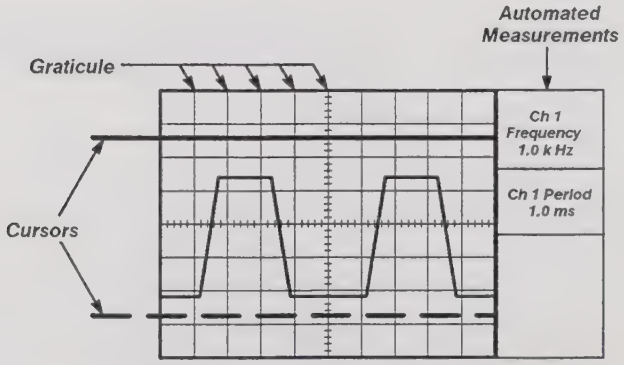


Figure 2-4: Examples of Three Measurement Classes

- the **save and document** system, which saves and retrieves waveform data or setup information for later analysis, reporting, or archiving (Figure 2-5). This system also can make hardcopies of the display. See page 2-29.

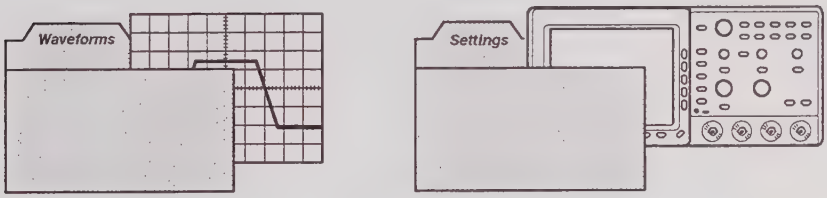


Figure 2-5: Save Waveforms and Settings

- the **remote communications** system, which uses the GPIB interface to connect the oscilloscope with other instruments. You can use a computer to remotely control the digitizing oscilloscope or read measurements for later analysis and storage (Figure 2-6). You can also set up the oscilloscope to send a screen hardcopy to a printer or plotter. See page 2-31.

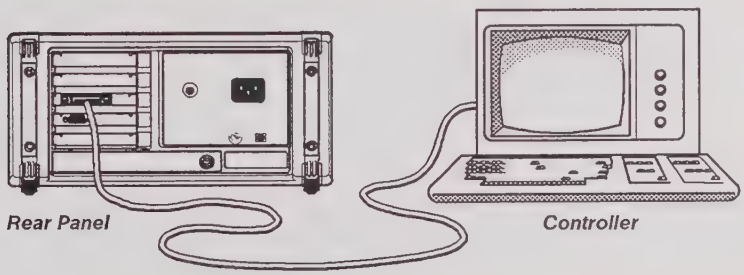


Figure 2-6: GPIB Connection Between the Oscilloscope and a Controller

Triggering

Triggers determine when the digitizing oscilloscope starts acquiring and displaying a waveform. They help create meaningful waveforms from unstable jumbles or blank screens (see Figure 2-7).

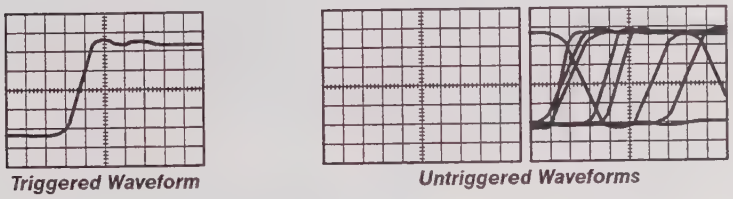


Figure 2-7: Examples of Triggered Waveforms

When a trigger event occurs, the digitizing oscilloscope starts acquiring samples to build a waveform record. The trigger event establishes the time-zero point in the waveform record, and all samples are measured with respect to that event. Once a trigger is recognized, the digitizing oscilloscope will not accept another trigger until acquisition is complete.

The basic trigger is the edge trigger. An edge trigger event occurs when the trigger *source* (the signal that the trigger circuit monitors) passes through a specified voltage *level* in a specified direction (the trigger *slope*). Besides the edge trigger the TDS 400 digitizing oscilloscopes have an optional video trigger.

Trigger Sources

You can derive your trigger from various sources. Trigger sources can be:

- any of the four input channels,
- the AC line voltage, or
- an auxiliary trigger input (on the rear panel).

Input Channel

The normal trigger source is any one of the four input channels. The channel you select as a trigger source will function whether it is displayed or not.

AC Line Voltage

Triggering on the AC Line Voltage is useful when you're looking at signals related to the power line frequency. Examples include devices like lighting equipment and power supplies. Because the digitizing oscilloscope generates that trigger, you do not have to input a signal to create it.

Auxiliary Trigger

This trigger source is useful in digital design and repair. For example, you might want to trigger with an external clock or with a signal from another part of the circuit. To use the auxiliary trigger, connect the external triggering signal to the Auxiliary Trigger input connector on the oscilloscope rear panel.

Types

The digitizing oscilloscope can provide two types of triggers: edge and an optional video trigger.

Edge Trigger

The edge trigger is considered the "basic" trigger. You can use it with both analog and digital test circuits. An edge trigger event occurs when the trigger *source* (the signal the trigger circuit is monitoring) passes through a specified voltage *level* in the specified direction (the trigger *slope*).

Edge triggers are available through both the main and the delayed trigger system. (The delayed trigger system is explained on page 2-10.)

Video Trigger (Optional)

A video trigger helps simplify the triggering and viewing of video (TV) signals. The video trigger option lets you trigger on positive or negative sync pulses. It lets you select interlaced field one, interlaced field two, both fields, or noninterlaced. You also can define the signal to be NTSC, PAL, SECAM, or a custom class.

Sync Pulses – since sync pulses occur at the end of each line and picture in a video signal, they are the logical event to trigger on. The oscilloscope can trigger on a positive or negative sync pulse. Although the standard polarity for video signals is negative, the positive polarity option is useful when probing circuitry that inverts a video signal.

Interlacing and Fields – a video picture or *frame* is drawn using two separate video signals called *fields*. The two fields alternate drawing the horizontal lines in a frame: *field one* is the field that draws all the odd numbered lines, and *field two* draws all the even number lines. *Interlacing* is the act of drawing a frame by alternating between field one and field two (see Figure 2-8).

Some video formats, especially those used in computer monitors, use noninterlaced formats.

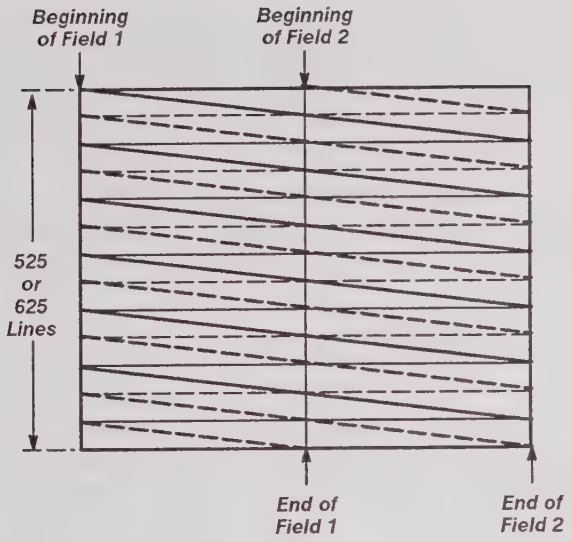


Figure 2-8: Interlaced Frame

The oscilloscope lets you choose between triggering on interlaced field one, interlaced field two, or triggering alternately on field one and field two (both fields).

Video Standards—Since video signals are used to transmit television signals, they are highly standardized. There are three dominant standards in the world today: *NTSC*, *PAL*, and *SECAM*.

- The NTSC standard was developed in the United States and is used in the U.S., Canada, and Japan. It has a line rate of 525 lines per frame and a field rate of 60 Hz.
- The PAL standard is used in Europe and many other parts of the world. It generally has a line rate of 625 lines per frame and a field rate of 50 Hz.
- The SECAM standard is used in France and USSR. It generally has a line rate of 625 lines per frame and a field rate of 50 Hz.

The oscilloscope lets you select from three predefined setups (NTSC, PAL, or SECAM), or you can customize the setup. The custom option lets you analyze the wide variety of video signals that don't adhere to NTSC, PAL, or SECAM standards. That option has several frequency ranges to choose from.

Trigger Modes

The trigger mode determines how the oscilloscope behaves in the absence of a trigger event. The digitizing oscilloscope provides two different trigger modes: *normal* and *automatic*.

Normal trigger mode lets the oscilloscope acquire a waveform only when it is triggered. If no trigger occurs, the oscilloscope will not acquire a waveform.

Automatic trigger mode (auto mode) lets the oscilloscope acquire a waveform even if a trigger doesn't occur. That mode uses a timer that starts after a trigger event occurs. If another trigger event is not detected before the timer runs out, the oscilloscope generates another trigger anyway. The length of time it waits for a trigger event depends on the time base setting.

The automatic mode ignores the trigger level. This is particularly useful when observing signals with a changing amplitude pattern, because you don't have to readjust the trigger level.

Holdoff

When a trigger event is recognized, the oscilloscope disables the trigger system until acquisition is complete. In addition, the trigger system remains disabled during the holdoff period that follows each acquisition. That adjustable holdoff time ensures a stable display.

For example, the trigger signal can be a complex waveform with many possible trigger points on it. Though the waveform is repetitive, a simple trigger might get you a series of patterns on the screen instead of the same pattern each time.

Digital pulse trains are good examples (see Figure 2-9). Each pulse looks like any other, so many possible trigger points exist. Not all of these will result in the same display. The holdoff period allows the digitizing oscilloscope to trigger on the correct edge resulting in a stable display.

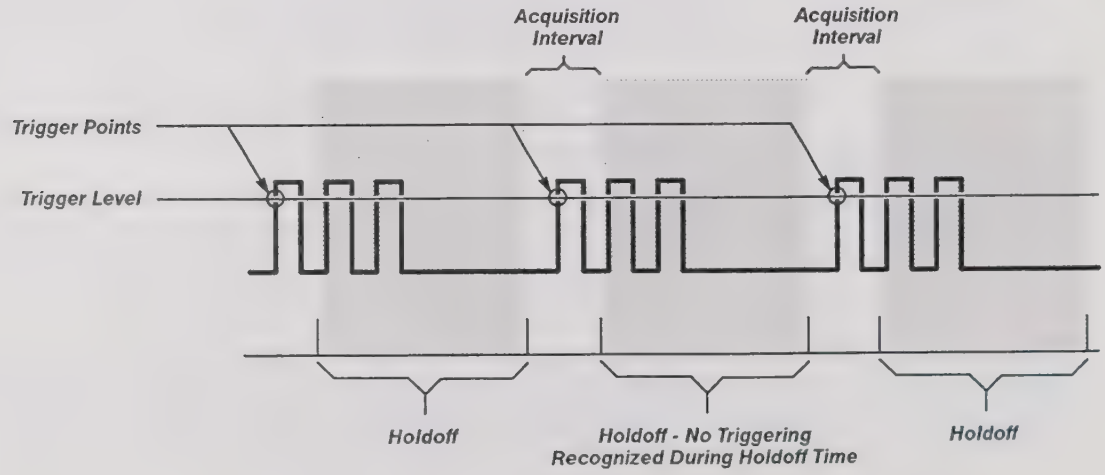


Figure 2-9: Trigger Holdoff Time Ensures Valid Triggering

Coupling

Trigger coupling determines what part of the signal is passed to the trigger circuit. Available coupling types include: AC, DC, Low Frequency Rejection, High Frequency Rejection, and Noise Rejection.

DC

- *DC coupling* passes all of the input signal. In other words, it passes both AC and DC components to the trigger circuit.

AC ∿

- *AC coupling* passes only the alternating components of an input signal (above 30 Hz). It removes the trigger signal's DC components.

In addition, the trigger system also has *high frequency rejection, low frequency rejection* and *noise rejection*. These eliminate specific frequency components (noise) from the trigger signal.

- *High frequency rejection* removes the high frequency portion of the triggering signal. That allows only the low frequency components to pass on to the triggering system to start an acquisition. On the digitizing oscilloscope, high frequency rejection attenuates signals above 30 kHz.

- *Low frequency rejection* does the opposite of high frequency rejection. Low frequency rejection attenuates signals below 80 kHz.
- *Noise Rejection* provides low DC sensitivity. It requires additional signal amplitude for stable triggering, reducing the chance of falsely triggering on noise.

Trigger Position

The adjustable *trigger position* defines where on the waveform record the trigger occurs. It lets you properly align and measure data within records. The top part of the display has an icon indicating where the trigger occurs in the waveform record.

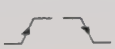
The part of the record that occurs *before* the trigger is the pretrigger portion. The part that occurs *after* the trigger is the posttrigger portion. You choose what percentage of the waveform record will contain pretrigger information. Many users find keeping pretrigger information a valuable troubleshooting technique.

For example, if you're trying to find the cause of an unwanted glitch in your test circuit, it may prove valuable to trigger on the glitch and make the pretrigger period large enough to capture data before the glitch. By analyzing what happened before it, you may uncover clues about the source of the glitch.

You define how much of the waveform record will be pretrigger and posttrigger in the Horizontal menu.

Slope and Level

The slope control determines whether the oscilloscope finds the trigger point on the rising or the falling edge of a signal (see Figure 2-10).



You set trigger slope with the Main Trigger menu **Slope** item and the resulting side menu's rising or falling slope icons.

The level control determines where on that edge the trigger point occurs (see Figure 2-10).

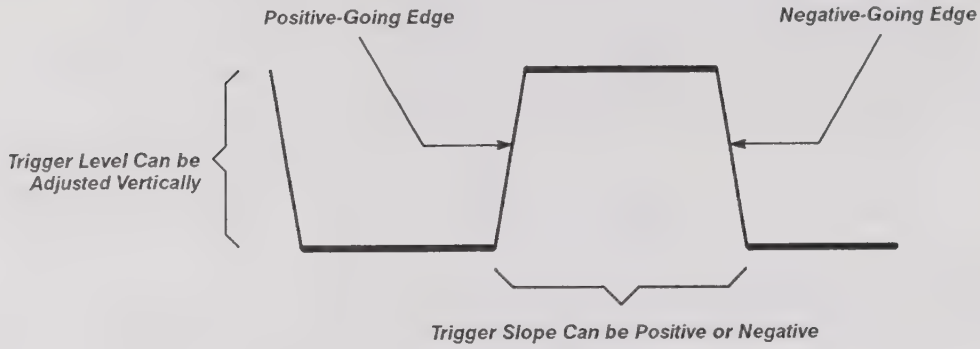

Positive-Going Edge
Negative-Going Edge
Trigger Level Can be Adjusted Vertically
Trigger Slope Can be Positive or Negative

Figure 2-10: Slope and Level Controls Help Define the Trigger

The digitizing oscilloscope lets you set the main trigger level with the trigger **MAIN LEVEL** knob.

Delay

You can also delay the trigger an absolute time or a set number of trigger events after a main trigger event.

The digitizing oscilloscope provides a conventional edge trigger for the delayed time base. The delayed time base will not trigger if the main trigger type is edge with its source set to auxiliary or if it is a video trigger. The Video menu has a delay option if you want to delay the video trigger.

There are two main types of delayed triggering (see Figure 2-11).

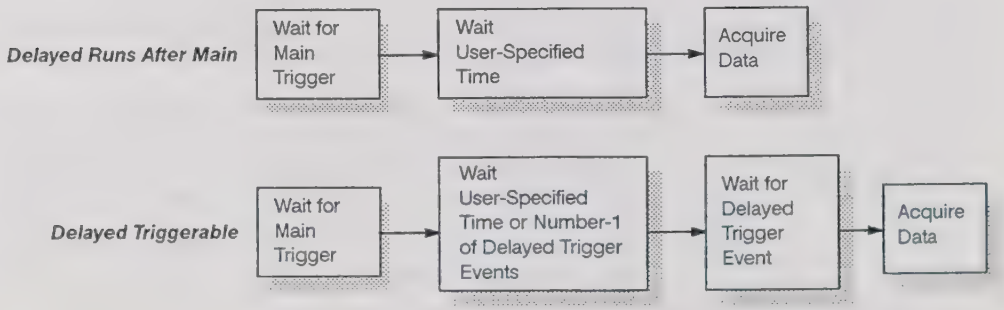
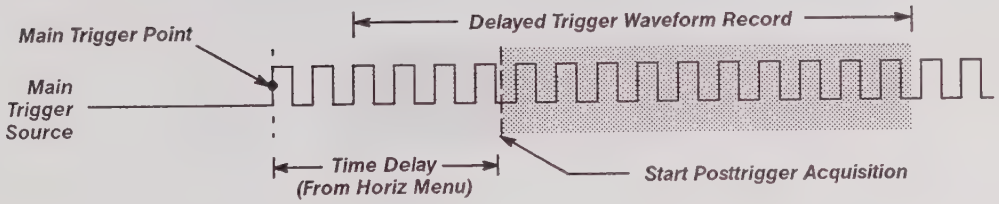


Figure 2-11: Delayed Triggering

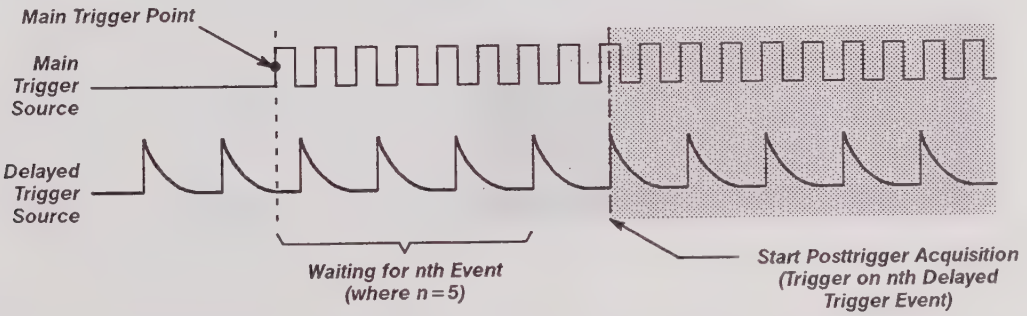
- *Delayed runs after main* looks for a main trigger, then waits a user-defined time, and then starts acquiring (see Figure 2-12).

- *Delayed triggerable* looks for a main trigger, then waits a user-defined time or number–1 of delayed trigger events, then triggers on the next delayed trigger event (see Figure 2-12).

Delayed Runs After Main



Delayed Triggerable By Events


Main Trigger Point
Main Trigger Source
Delayed Trigger Source
Waiting for nth Event (where n=5)
Start Posttrigger Acquisition (Trigger on nth Delayed Trigger Event)

Delayed Triggerable By Time

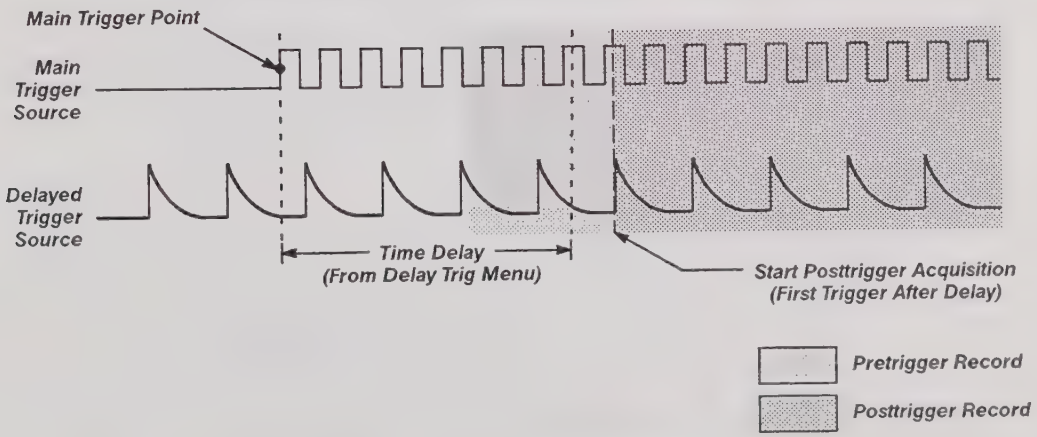


Figure 2-12: How the Delayed Triggers Work

For More Information

See *Delayed Triggering*, on page 3-23.

See *Edge Triggering*, on page 3-35.

See *Triggering*, on page 3-101.

See *Video Triggering*, on page 3-111.

Acquisition

The acquisition process converts the analog input signal to digital. The oscilloscope creates a digital representation of the input signal by sampling the voltage level of the signal at regular time intervals (Figure 2-13).

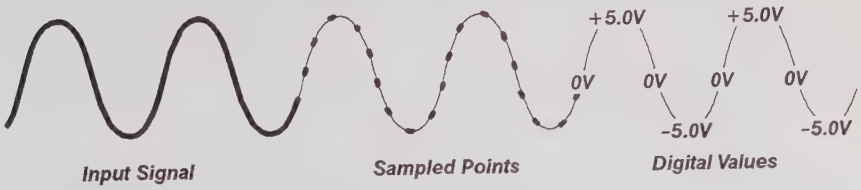


Figure 2-13: Acquisition: Input Analog Signal, Sample, and Digitize

The sampled points are stored in memory along with corresponding timing information. You can use this digital representation of the signal for display, measurements, or further processing.

You specify how the digitizing oscilloscope acquires data points and assembles them into the waveform record.

Sampling and Digitizing

The trigger marks time zero in a waveform record. All record points before the trigger event make up the pretrigger portion of the the waveform record. Every record point after the trigger event is part of the posttrigger portion. All timing measurements in the waveform record are made relative to that trigger event.

Each time it takes a sample, the digitizer produces a numeric representation of the signal at that time. The number of samples may be larger than the number of points in your waveform record. In fact, the oscilloscope may take several samples for each record point (Figure 2-14).

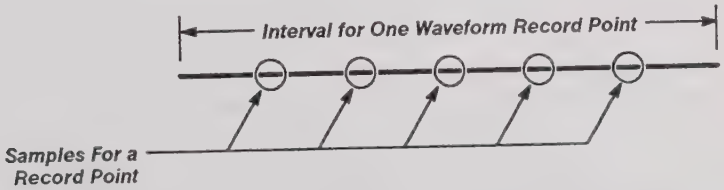


Figure 2-14: Several Points May be Acquired for Each Point Used

The digitizer can use the extra samples to perform additional processing, such as averaging, or looking for minimum and maximum values.

The digitizing oscilloscope creates a waveform record containing a user specified number of data points. Each record point represents a certain voltage level that occurs a determined amount of time from the trigger event.

Record Length

The number of points that make up the waveform record is defined by the record length. You can set the record length in the instrument's Horizontal menu. The digitizing oscilloscope provides record lengths of 500, 1000, 2500, and 5000 points. You can order a record length option that provides additional record lengths of 15,000 and 30,000 points. That option is available only at the time of original purchase. It cannot be added in the field.

Sampling

Sampling is the process of converting the analog input signal to digital for display and processing. The two general methods of sampling are *real-time* and *equivalent-time*.

Real-Time Sampling—In real-time (RT) sampling, the oscilloscope digitizes all the points it acquires after one trigger event (see Figure 2-15). Use real-time sampling to capture single-shot or transient events.

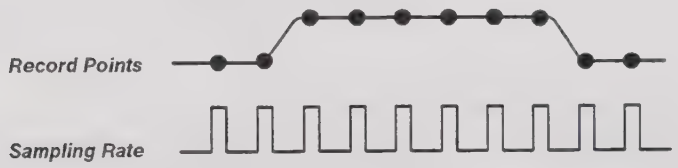


Figure 2-15: Real-Time Sampling

Turning the horizontal **SCALE** knob clockwise causes the scope to assign shorter time periods to the waveform record. The smaller the time period gets, the faster the oscilloscope needs to acquire record points to fill up the record.

As long as the digitizing oscilloscope can acquire enough points for a waveform record after one trigger event, it will remain in the real-time sample mode. The TDS 400 always uses real-time sampling when the time base is 500 ns or slower. For speeds faster than 500 ns, you can either limit the oscilloscope to real-time sampling or allow equivalent-time sampling. You make that choice in the Acquisition menu.

If the digitizing oscilloscope is limited to real-time sampling and you turn the horizontal **SCALE** knob to a point that the time base is faster than 500 ns, the digitizing oscilloscope will not acquire enough samples for a complete waveform record. When that happens, the digitizing oscilloscope uses a process called interpolation to create the intervening points in the waveform record. There are two options for interpolation: linear or sin(x)/x.

Linear interpolation computes record points between actual acquired samples by using a straight line fit. It assumes all the interpolated points fall in their appropriate point in time on that straight line. That is useful for many waveforms like pulse trains.

Sin(x)/x interpolation computes record points using a curve fit between the actual values acquired. It assumes all the interpolated points fall along that curve. That is particularly useful when acquiring more rounded waveforms like sine waves. Actually, it is appropriate for general use, although it may introduce some overshoot or undershoot in signals with fast rise times.

Equivalent-Time Sampling—The digitizing oscilloscope only uses equivalent-time sampling if you have enabled the equivalent-time option in the Acquisition menu and the time base is faster than 500 ns.

In equivalent-time (ET) sampling the oscilloscope acquires samples over many repetitions of the event (Figure 2-16). It should only be used on repetitive signals.

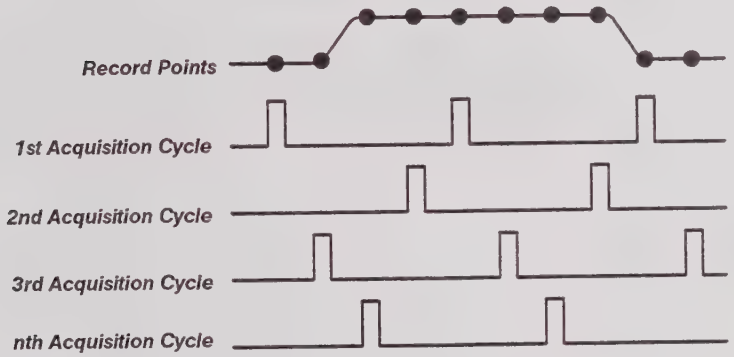


Figure 2-16: Equivalent-Time Sampling

The oscilloscope takes a few samples with each trigger event, and eventually constructs a waveform record using the samples from multiple acquisitions. That feature lets you accurately acquire signals with frequencies much higher than the digitizing oscilloscope's real-time sample rate.

The digitizing oscilloscope uses a type of equivalent-time sampling called *random equivalent-time sampling*. Although the samples are taken sequentially in time, they are random with respect to the trigger. That is because the oscilloscope's sample clock runs asynchronously with respect to the input signal and the signal trigger. The oscilloscope takes samples independent of the trigger position and displays them based on the time difference between the sample and the trigger.

Acquisition Modes

The acquisition mode you select determines how the several samples taken during a single acquisition interval are combined into a record point.

The digitizing oscilloscope supports five acquisition modes. They are:

- *sample*
- *peak detect*
- *hi res*
- *envelope*
- *average*

The first three modes (sample, peak detect, and hi res) operate in real-time on a single trigger event, provided the digitizing oscilloscope can acquire enough samples for each trigger event.

The last two modes (envelope and average) operate on multiple acquisitions. The digitizing oscilloscope averages or envelopes several waveforms on a point-by-point basis.

Figure 2-17 illustrates the different modes and lists the benefits of each. It will help you select the appropriate mode for your application.

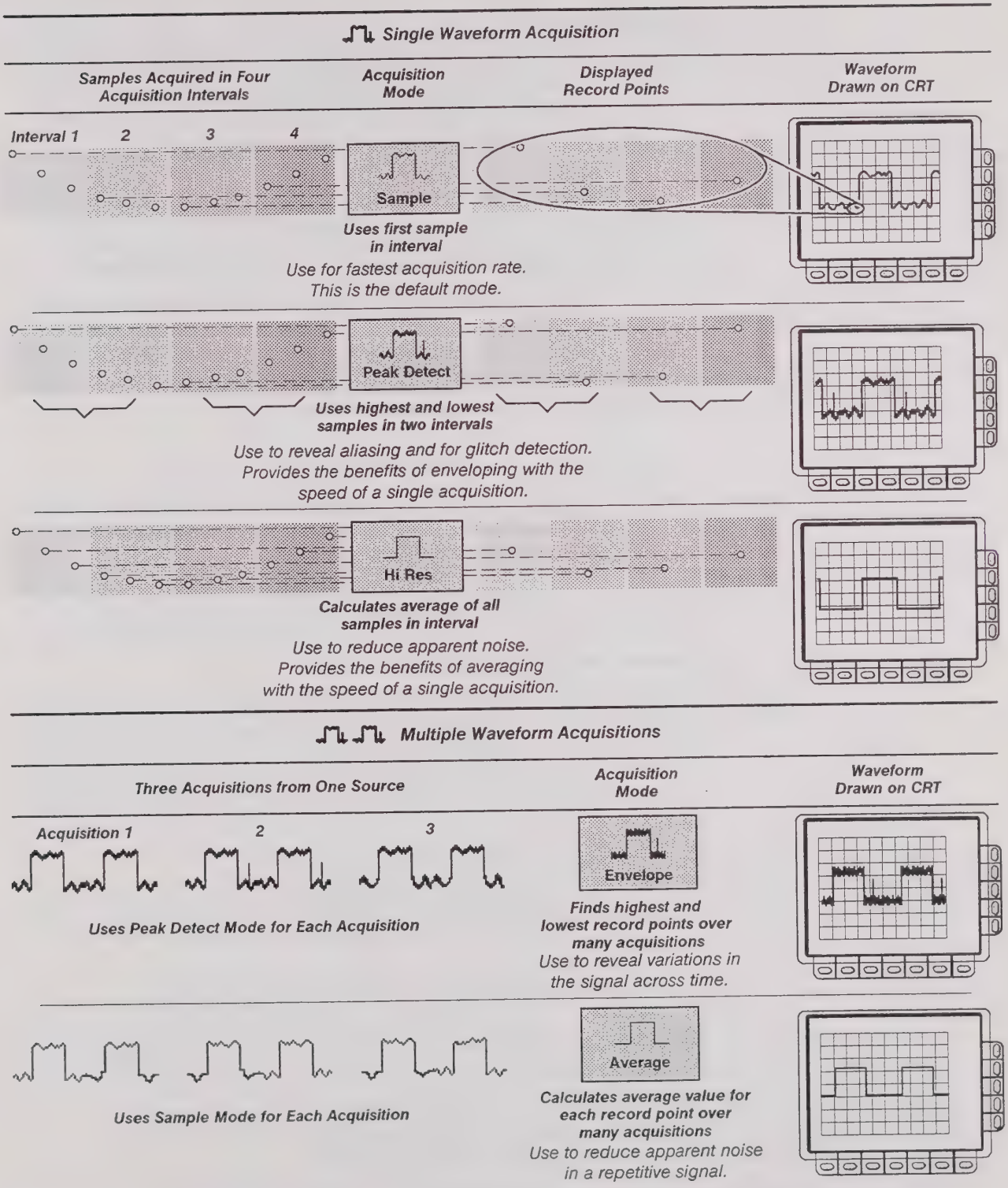

Single Waveform Acquisition
Samples Acquired in Four Acquisition Intervals
Acquisition Mode
Displayed Record Points
Waveform Drawn on CRT
Interval 1
2
3
4
Sample
Uses first sample in interval
Use for fastest acquisition rate.
This is the default mode.
Peak Detect
Uses highest and lowest samples in two intervals
Use to reveal aliasing and for glitch detection.
Provides the benefits of enveloping with the speed of a single acquisition.
Hi Res
Calculates average of all samples in interval
Use to reduce apparent noise.
Provides the benefits of averaging with the speed of a single acquisition.
Multiple Waveform Acquisitions
Three Acquisitions from One Source
Acquisition Mode
Waveform Drawn on CRT
Acquisition 1
2
3
Uses Peak Detect Mode for Each Acquisition
Envelope
Finds highest and lowest record points over many acquisitions
Use to reveal variations in the signal across time.
Uses Sample Mode for Each Acquisition
Average
Calculates average value for each record point over many acquisitions
Use to reduce apparent noise in a repetitive signal.

Figure 2-17: How the Acquisition Modes Work

Sample Mode

In Sample mode, the oscilloscope creates a record point by saving the first sample (of perhaps many) during each acquisition interval. (An acquisition interval is the time covered by the waveform record divided by the record length.) This is the default mode.

Peak Detect Mode

Peak Detect mode saves the highest and lowest sample in two adjacent intervals. That mode only works with real-time, non-interpolated sampling.

For many glitch-free signals, this mode is indistinguishable from the sample mode. Also, if you set the the time base so fast (faster than 500 ns) that it requires real-time interpolation or equivalent-time sampling, the mode automatically changes from peak detect to sample, although the menu selection will not change.

Hi Res Mode

In Hi Res mode, the digitizing oscilloscope averages all samples taken during an acquisition interval to create a record point. That average results in a higher-resolution, lower-bandwidth waveform.

This mode only works with real-time, non-interpolated sampling. If you set the time base so fast (faster than 500 ns) that it requires real-time interpolation or equivalent-time sampling, the mode automatically becomes sample, although the menu selection will not change.

A key advantage of Hi Res is its potential for increasing resolution regardless of the input signal. The equations shown below illustrate how you can obtain up to 15 significant bits with Hi res mode (Table 2-1). Note that the resolution improvements are limited to speeds slower than 1 μs/div. Also, resolutions above 15 bits are not allowed by internal hardware and computation limitations.

$$Si = \text{Sampling Interval for TDS 400} = 10\ ns$$

$$\Delta t = \text{Sample Interval} = \frac{\text{Time/Div}}{\text{Number Of Points/Div}} = \frac{10\ \mu s/Div}{50\ \text{Points/Div}} = 200\ ns$$

$$Nd = \text{Number of points per decimation interval} = \frac{\Delta t}{Si} = 20$$

$$\text{Resolution Enhancement (bits)} = 0.5 \times LOG_2(Nd) \approx 2\ \text{extra bits}$$

Table 2-1: Additional Resolution Bits

Time Base Speed	Bits of Resolution
1 µs and faster	8 bits
2 µs to 5 µs	9 bits
10 µs to 20 µs	10 bits
50 µs to 100 µs	11 bits
200 µs to 500 µs	12 bits
1 ms to 2 ms	13 bits
5 ms	14 bits
10 ms and slower	15 bits

Envelope Mode

Envelope mode lets you acquire and display a waveform record that shows the extremes in variation over several acquisitions. You specify the number of acquisitions over which to accumulate the data. The oscilloscope saves the highest and lowest values in two adjacent intervals similar to the peak detect mode. But envelope mode, unlike peak detect, gathers peaks over many trigger events.

After each trigger event, the oscilloscope acquires data and then compares the min/max values from the current acquisition with those stored from previous acquisitions. The final display shows the most extreme values for all the acquisitions for each point in the waveform record.

Average Mode

Average mode lets you acquire and display a waveform record that is the averaged result of several acquisitions. This mode reduces random noise. The oscilloscope acquires data after each trigger event using the sample mode. It then averages the record point from the current acquisition with those stored from previous acquisitions.

Bandwidth

Bandwidth refers to the range of frequencies which an oscilloscope can acquire and display accurately (with less than 3 dB attenuation).

You can set different bandwidths with the digitizing oscilloscope. Lower bandwidth settings let you eliminate a signal's higher frequency components. The TDS 400 offers **Full**, **100 MHz,** and **20 MHz** bandwidth settings.

Coupling

You can couple your input signal to the digitizing oscilloscope three ways. You can choose between AC, DC, or Ground (GND). You also can set the input impedance.

DC

- DC coupling shows both the AC and DC components of an input signal.

AC ∿

- AC coupling show only the alternating components of an input signal.

GND

- Ground (GND) coupling disconnects the input signal from the acquisition.

Ω

- Input impedance lets you select either 1 MΩ or 50 Ω impedance.

NOTE

If you select 50 Ω impedance with AC coupling, the digitizing oscilloscope will not accurately display frequencies under 200 kHz.

For More Information

See *Scaling and Positioning Waveforms*, on page 2-21.

See *Acquisition Modes*, on page 3-13.

Scaling and Positioning Waveforms

Scaling and positioning waveforms means increasing or decreasing their displayed size and moving them up, down, right, and left on the display.

Two display icons, ground and the record view, help you quickly see the position of the waveform in the display (see Figure 2-18). The ground icon points to the ground of the waveform record. The record view, at the top of the display, indicates where the trigger occurs and what part of the waveform record is displayed.

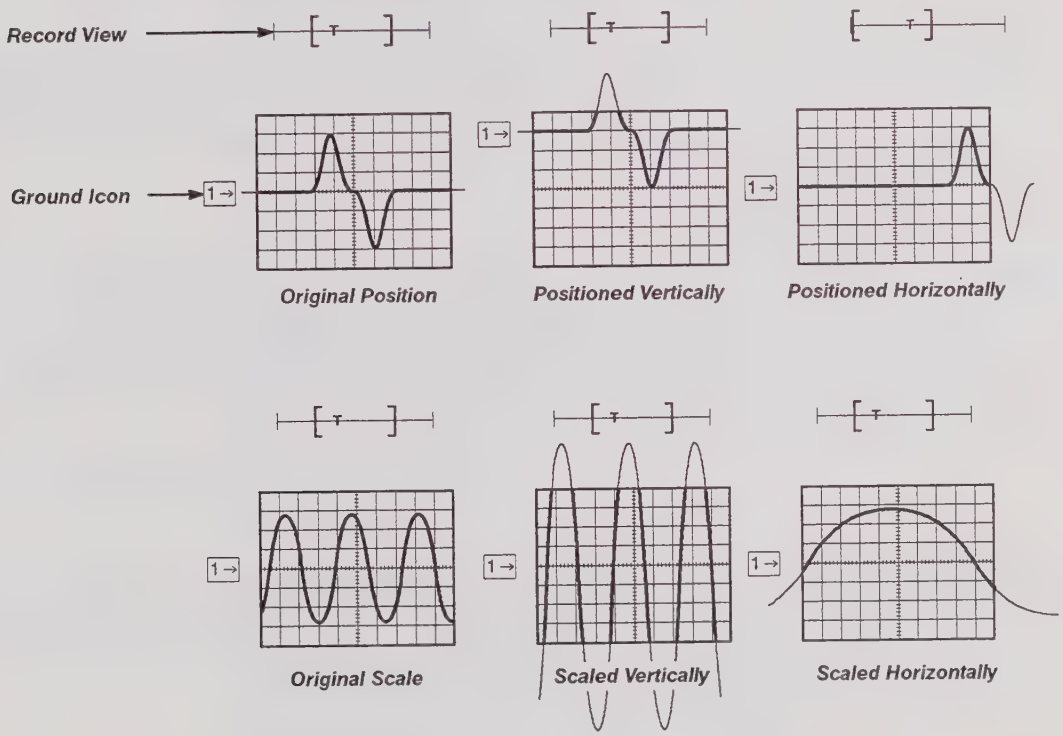


Figure 2-18: Scaling and Positioning

Vertical System

You can adjust the vertical position of the selected waveform by moving it up or down on the display. For example, when trying to compare multiple waveforms, you can put one above another and compare them, or you can overlay the two waveforms on top of each other. To move the selected waveform turn the vertical **POSITION** knob clockwise.

You can also alter the vertical scale. The digitizing oscilloscope shows the scale (in volts per division) for each selected channel toward the bottom left of the display. As you turn the vertical **SCALE** knob clockwise, the value de-

creases resulting in higher resolution because you see a smaller part of the waveform. As you turn it counter-clockwise the scale increases allowing you to see more of the waveform but with lower resolution.

Besides using the position and scale knobs, you can set the vertical scale and position with exact numbers. You do that with the Vertical menu **Fine Scale** and **Position** selections and the general purpose knob.

Offset

Vertical offset changes where the ground reference point is shown with respect to the graticule. Offset adds volts to the reference point without changing the scale. That feature allows you to move the waveform up and down over a large area without decreasing the resolution.

Offset is useful in cases where a waveform has a DC bias. One example is looking at a small ripple on a power supply output. You may be trying to look at a 100 mV ripple on top of a 15 V supply. The range available with offset can prove valuable as you try to move and scale the ripple to meet your needs.

Horizontal System

Adjusting the horizontal position of waveforms moves them right or left on the display. That is useful when the waveform's record length is so large (greater than 500 points) that the digitizing oscilloscope cannot display the entire waveform record at one time. You can also adjust the scale of the waveform. For example, you might want to see just one cycle of a waveform to measure the overshoot on its rising edge.

You adjust the horizontal scale of the displayed waveform records using the horizontal **SCALE** knob and the horizontal position using the horizontal **POSITION** knob.

The digitizing oscilloscope shows the actual scale in the bottom right of the display. The scale readout shows the time per division used. Since all live waveforms use the same time base, the digitizing oscilloscope only displays one value for all the selected channels.

Aliasing

When *aliasing* happens, you see a waveform record with a frequency lower than the actual waveform. Aliasing occurs because the oscilloscope cannot acquire the signal fast enough to construct an accurate waveform record (Figure 2-19).

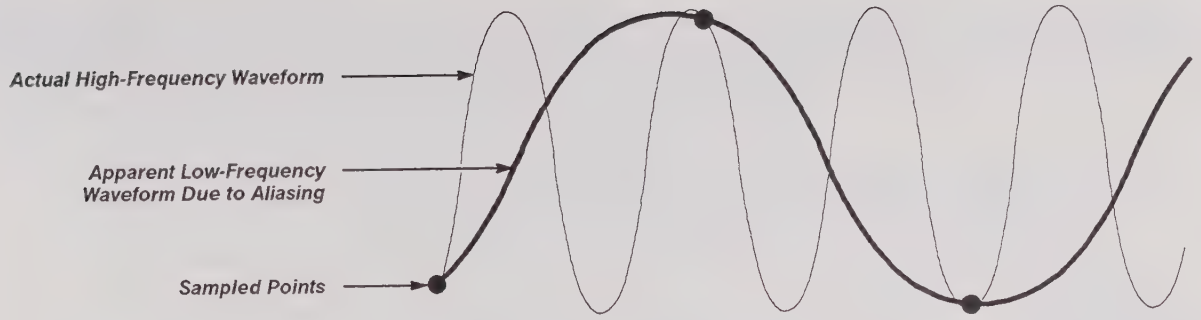


Figure 2-19: Aliasing

One simple way to check for aliasing is to slowly change the horizontal scale (time per division setting). If the shape of the displayed waveform changes drastically, you may have aliasing.

In order to represent a signal accurately and avoid aliasing, you must sample the signal at least twice as fast as the highest frequency component. For example, a signal with frequency components of 50 MHz would need to be sampled at a rate of 100 Megasamples/second or faster.

There are various ways to prevent aliasing. Try adjusting the horizontal scale or simply press the **AUTOSET** button. You can also counteract some aliasing by changing the acquisition mode in the Acquisition menu. For example, if you're using the sample mode and suspect aliasing, you may want to change to the peak detect mode. Since the peak detect mode searches for samples with the highest and lowest values, it can detect faster signal components.

Delayed Time Base

You can set a main time base and a delayed time base. Each time base has its own trigger. The delayed time base has two additional parameters that describe its triggering relationship to the main time base. These are: 1) delayed runs mode and 2) delay amount (time or events). The delayed time base is useful in catching events that follow other events. See *Triggering* on page 2-5 for more information on the delayed trigger.

Zoom

You can use zoom to see more detail without changing the acquired signal. When you press the **ZOOM** button, a portion of the waveform record can be expanded or compressed on the display but the record points stay the same. For example, you might have acquired a single-shot event and want to magnify the display, but if you change the time base the waveform would disappear. Use zoom instead.

The zoom feature is also handy if you've acquired data while using the maximum time per division and want to magnify the results.

Autoset

Autoset lets you quickly obtain a stable waveform display. It automatically adjusts a wide variety of settings including vertical and horizontal scaling. Other settings affected include trigger coupling, type, position, slope, mode, and display intensities. *Autoset* on page 3-17 describes in detail what autoset does.

For More Information

See *Autoset*, on page 3-17.

See *Delayed Triggering*, on page 3-23.

See *Horizontal Control*, on page 3-49.

See *Vertical Control*, on page 3-107.

See *Zoom*, on page 3-119.

The digitizing oscilloscope not only displays graphs of voltage versus time, it also can help you measure the displayed information (see Figure 2-20).

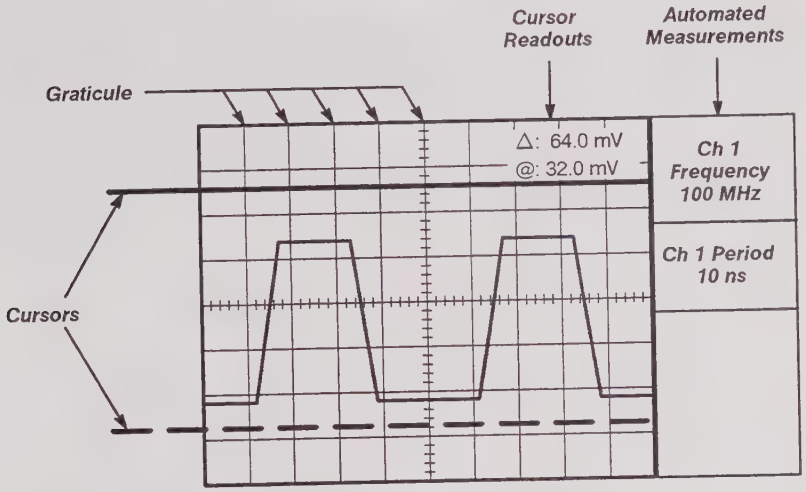


Figure 2-20: Graticule, Cursor and Automated Measurements

Measurement Sources

The oscilloscope provides three measurement classes. They are: graticules, cursors, and automated measurements.

Graticule Measurements

Graticule measurements provide you with quick, visual estimates. For example, you might look at a waveform's amplitude and say "it's a little more than 100 mV."

You can perform simple measurements by counting the number of major and minor graticule divisions involved and multiplying by the scale factor.

For example, if you counted five major vertical graticule divisions between a waveform's minimum and maximum values and knew you had a scale factor of 100 mV/division, then you could easily calculate your peak-to-peak voltage:

5 divisions × 100 mV/division = 500 mV.

Cursor Measurements

Cursors are fast and easy-to-understand measurements. You take measurements by moving the cursors and reading their numeric values.

Cursors appear in pairs. One part of the pair is *active* and the other *inactive*. You move the active cursor (the solid line) using the general purpose knob. The **TOGGLE** button lets you select (toggle) which cursor bar is active or inactive. The inactive cursor is a dashed line on the display.

The screen readout shows not only the values of the cursors but also the difference between them. These readouts are updated as you adjust cursor positions.

To get the cursor menu, press the **CURSOR** button. There are two kinds of cursors available in that menu: horizontal bar and vertical bar (Figure 2-21).

Horizontal Bar Cursors *Vertical Bar Cursors*

Figure 2-21: Cursor types

Horizontal bar cursors measure vertical parameters (typically volts). When using these cursors the screen readout shows the voltage level of the active horizontal bar relative to ground and the voltage difference between the two horizontal bars.

Vertical bar cursors measure horizontal parameters (typically time). When using these cursors the screen readout shows the time of the active vertical bar relative to the trigger and the time difference between the two vertical bars.

Automated Measurements

You make automated measurements merely by pressing a few buttons. The digitizing oscilloscope does all the calculating for you. Because these measurements use the waveform record points, they are more accurate than cursor or graticule measurements.

Press the **MEASURE** button for the automated measurement menus. These menus let you make *amplitude* and *timing* measurements. (See Appendix D for details on how the digitizing oscilloscope calculates each measurement.) You can select and display up to four measurements.

You can make automated measurements on the entire waveform record or just on a specific part. The gating option in the Measurement menu lets you use the vertical cursors to limit the measurement to a section of the waveform record.

Amplitude measurements are made on vertical parameters. This typically means voltage. They are minimum, maximum, high, low, positive overshoot, negative overshoot, peak to peak, amplitude, mean, cycle mean, RMS, and cycle RMS.

Timing measurements are made on horizontal parameters. This typically means seconds or Hertz. They are period, frequency, positive width, negative width, rise time, fall time, positive duty cycle, negative duty cycle, propagation delay, and burst width.

Automated measurements use readouts to show measurement status. These readouts are updated as the oscilloscope acquires new data or if you change settings.

For More Information

See *Tutorial Example 3: Automated Measurements*, on page 1-15.

See *Cursor Measurements*, on page 3-19.

See *Measurement System*, on page 3-55.

See *Appendix D: Algorithms*, on page A-75.

Save and Document

You can electronically save data or setup information for later analysis, reporting, or archiving (see Figure 2-22). For example, you can save waveforms and later compare them to other waveforms. You can also save setup information to help replicate test procedures.

You can print a copy of what is on the screen for analysis or documentation purposes, using the hardcopy function.

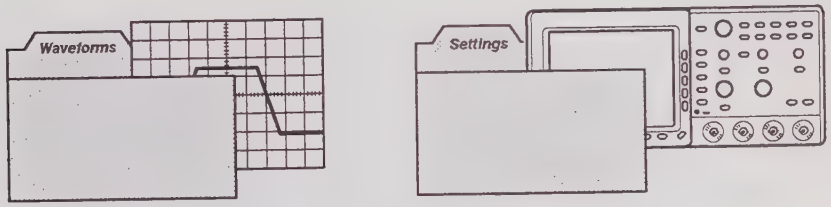


Figure 2-22: Save Setup and Waveform Data

Saving and Recalling Waveforms

A stored waveform is a record of a waveform. You can also think of it as a snapshot of a waveform.

The digitizing oscilloscope can save acquired waveforms in any one of four nonvolatile memories. You can later recall them, display them, and use them for a variety of tasks. For example, you might want to perform waveform math with a stored and a newly acquired waveform or compare a stored waveform with a newly acquired waveform.

Stored waveforms are not erased when you turn off the digitizing oscilloscope. They will be available when you turn the power back on.

If you run out of memory when you try to save a waveform, you can delete other references to make room for the new one. You'll know if you run out of memory because the digitizing oscilloscope will display a message.

The digitizing oscilloscope lets you save up to 60,000 waveform record points.

Saving and Recalling Setups

The digitizing oscilloscope can save front panel setups in any one of the ten nonvolatile memories. You can later recall them, recreating your testing situation accurately and quickly. Stored settings are not erased when you power off the digitizing oscilloscope. They are available when you turn the power back on.

You also can recall the factory setup at any time. *Appendix F* explains in detail what factory setup does.

Hardcopies

The digitizing oscilloscope can output a copy of exactly what's on the screen to a variety of graphics printers and plotters. The output includes waveforms, graticules and measurements.

The oscilloscope uses the GPIB port to interface with a printer. GPIB is described in more detail in the following article titled *Remote Communications*.

Different hardcopy devices use different formats. The digitizing oscilloscope supports several. These include HP Thinkjet, Deskjet, Laserjet, Epson®, Interleaf®, Postscript®, and HPGL. Some formats, particularly Interleaf, Postscript, and HPGL, are compatible with various desktop publishing packages. That means you can paste files created from the oscilloscope directly into a document on any of those desktop publishing systems.

You can send information in landscape or portrait format (Figure 2-23).

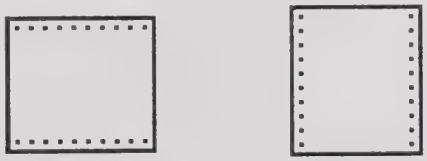


Figure 2-23: Hardcopy Formats

For More Information

See *Tutorial Example 4: Saving Setups*, on page 1-19.

See *Hardcopy*, on page 3-41.

See *Remote Communications* (Concepts), on page 2-31.

See *Remote Communication*, on page 3-89.

See *Saving and Recalling Setups*, on page 3-91.

See *Saving and Recalling Waveforms*, on page 3-93.

Remote Communications

You can use a computer to remotely set the oscilloscope's front panel controls or take measurements and read those measurements for further analysis or storage (see Figure 2-24). You can also set up the oscilloscope to make a hardcopy on a printer or a plotter.

The standard protocol for remote communications available on the digitizing oscilloscope is the General Purpose Interface Bus (GPIB or IEEE Std 488.2-1987).

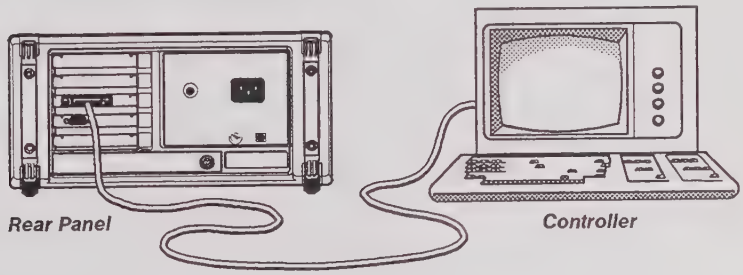


Figure 2-24: GPIB Enables Data Transfers Between the Oscilloscope and a Controller

GPIB Protocol

GPIB enables data transfers between instruments that support the GPIB protocols. It provides:

- Remote instrument control
- Bidirectional data transfer
- Device compatibility
- Status and event reporting

Besides the base protocols, Tektronix has defined codes and formats for messages to travel over GPIB. Each device that follows these codes and formats, such as the TDS 420 and TDS 460, supports standard commands. Use of instruments that support these commands can greatly simplify development of GPIB systems.

Why GPIB?

GPIB is a good solution for setups requiring speed (up to 1 Megabyte/second) and multiple instrument control (up to 15 devices on a bus). GPIB uses a parallel bus that provides faster data transfer rates than typical serial RS-232-C devices. The GPIB addressing scheme allows you to hook multiple instruments together in a system.

GPIB Setup

Before connecting devices to GPIB, you need to be áware of some rules about GPIB networks, cables, and connectors.

GPIB Interface Requirements

You can connect GPIB networks in many configurations if you follow these rules:

- You can include no more than 15 devices, including the controller, on a single bus.
- You must connect one device load every two meters (about six feet) of cable length to maintain bus electrical characteristics. Generally, each instrument represents one device load on the bus.
- The total cumulative cable length must not exceed 20 meters.
- You must power on at least two-thirds of the device loads when you use your network.
- You must have only one cable path from each device to each other device on your network (see Figure 2-25). You must not create loop configurations.

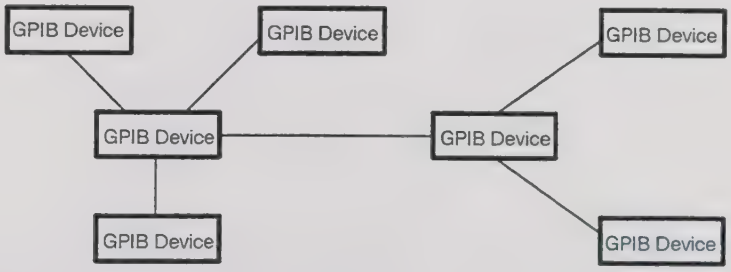


Figure 2-25: Typical GPIB Network Configuration

Cables—An IEEE Std 488.1-1987 GPIB cable (available from Tektronix) is required to connect two GPIB devices.

Connector – A 24-pin GPIB connector is located on the oscilloscope's rear panel. The connector has a D-type shell and conforms to IEEE Std 488.1-1987. You can stack GPIB connectors on top of each other (see Figure 2-26).

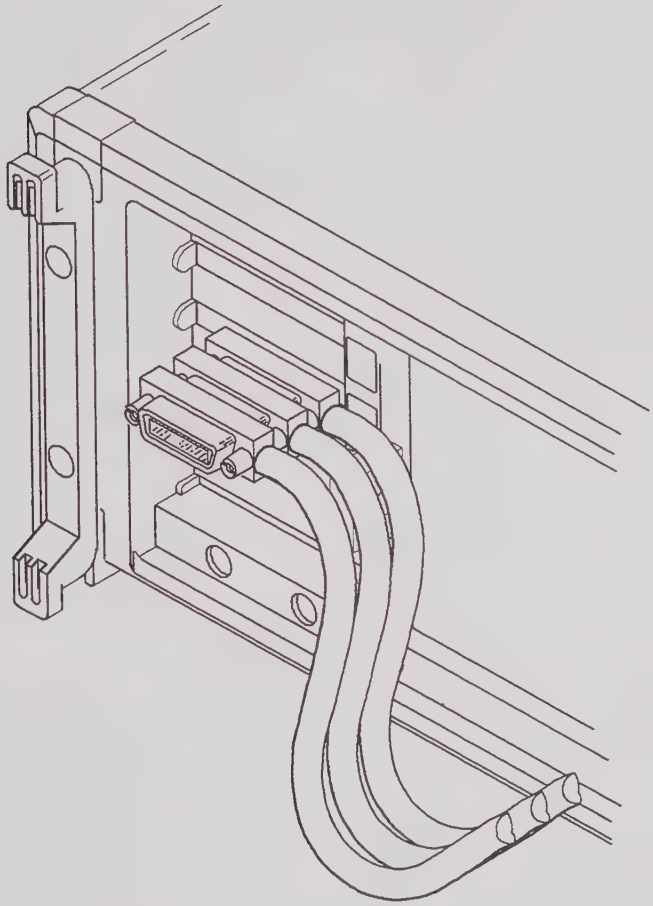


Figure 2-26: Stacking GPIB Connectors

GPIB Parameters

In the Utility menu you need to define two important GPIB parameters: *mode* and *address*. You need to set the mode to talker/listener, talk only, or take if off the bus. You also need to specify the primary communication address.

For More Information

See *Remote Communication*, on page 3-89.

In Detail

Replace this page with the tab divider of the same name.

Overview

This section describes the details of operating the digitizing oscilloscope.

The first part, *At a Glance*, quickly shows you how the oscilloscope is organized and gives some very general operating instructions. It also contains an overview of all the main menus. This part includes:

- Front Panel Map
- Rear Panel Map
- Display Map
- Basic Menu Operation
- Menu Map

The second part contains an alphabetical list of tasks you can perform with the digitizing oscilloscope. Use this section to answer specific questions about instrument operation. These tasks include:

- Acquisition Modes
- Autoset
- Cursor Measurements
- Delayed Triggering
- Display Modes
- Edge Triggering
- Hardcopy
- Help
- Horizontal Control
- Measurement System
- Probe Accessories
- Probe Compensation
- Probe Selection
- Remote Communication
- Saving and Recalling Setups
- Saving and Recalling Waveforms
- Selecting Channels
- Status
- Triggering

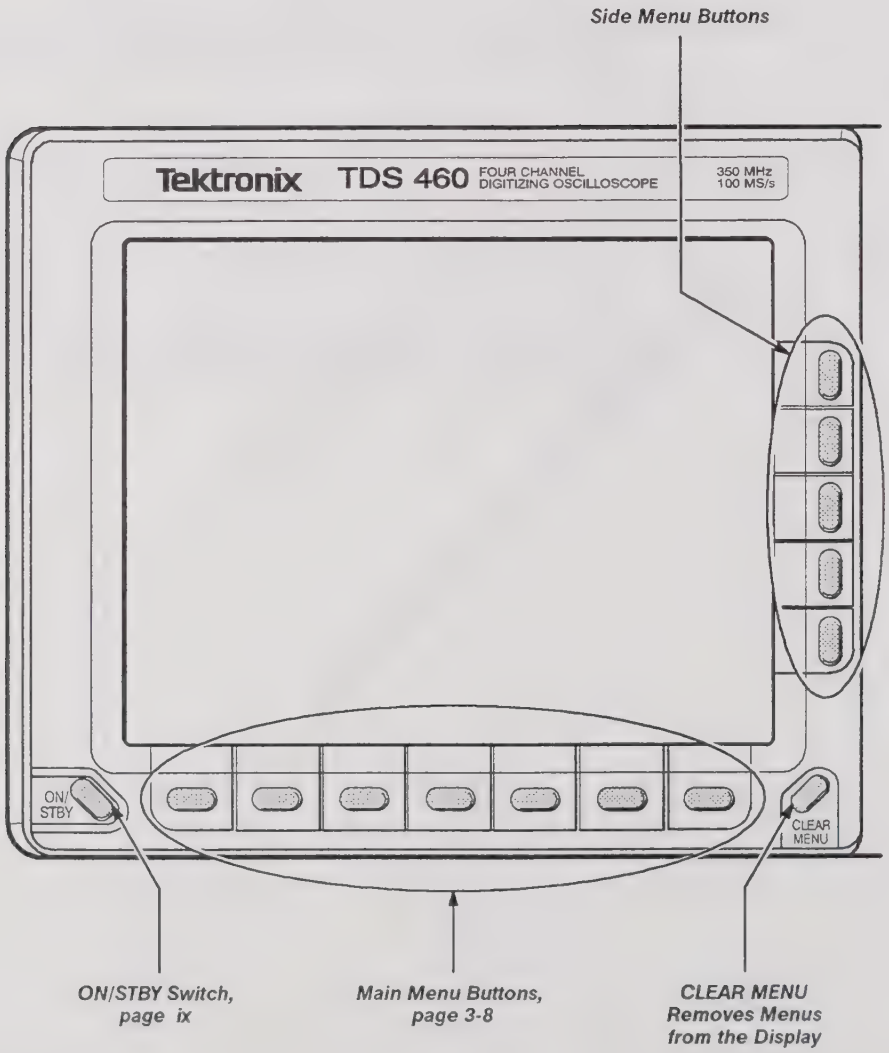
- Vertical Control
- Video Triggering
- Waveform Math
- Zoom

At a Glance

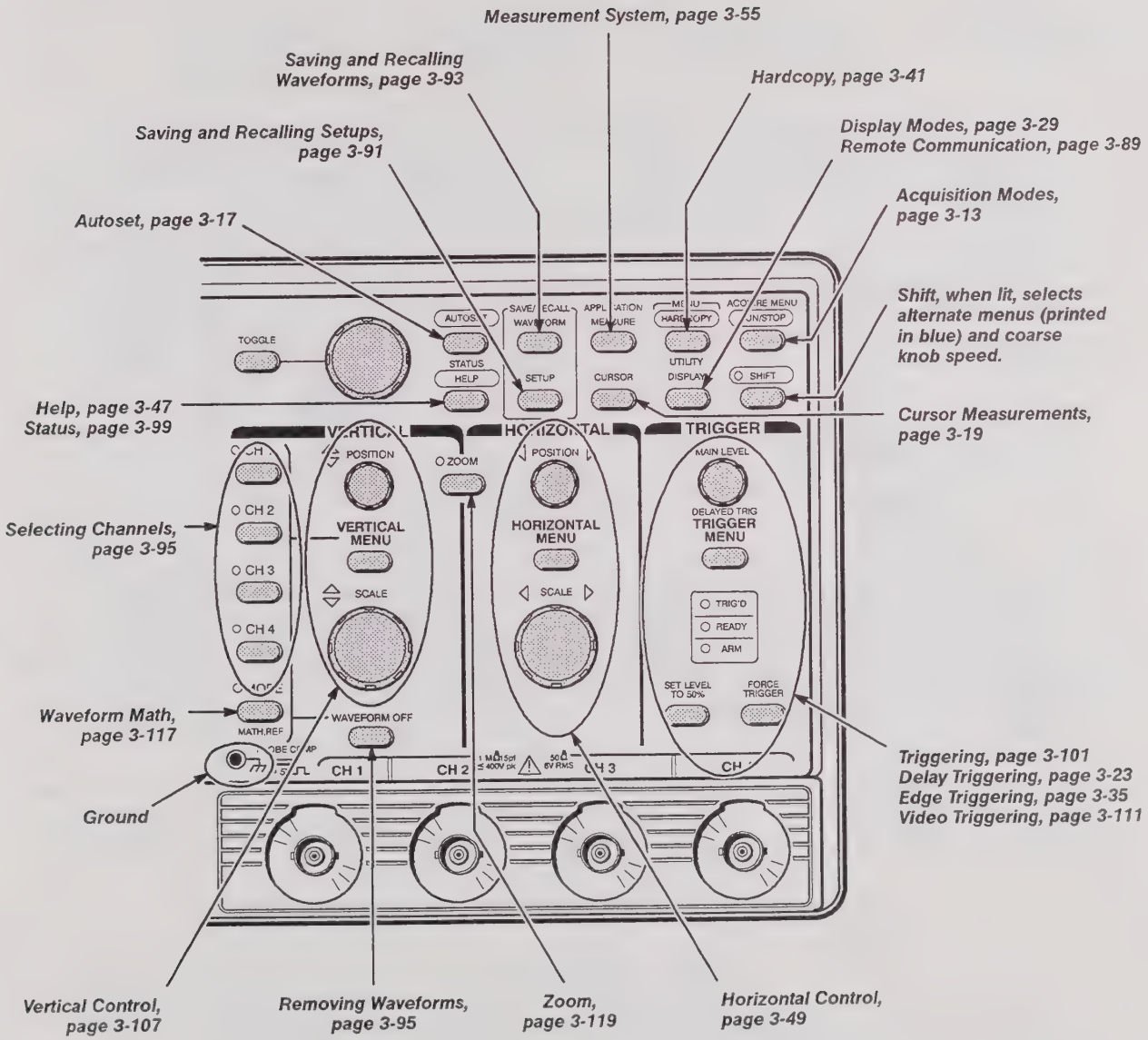
The *At a Glance* section contains illustrations of the display, front and rear panels, and menu system. These will help you understand and operate the digitizing oscilloscope. This section also contains a visual guide to using the menu system.

- *Front Panel Map* shows the locations and describe the purposes of the various buttons and knobs on the front panel of the digitizing oscilloscope.
- *Rear Panel Map* shows the various parts of your instrument's rear panel.
- *Display Map* shows a typical display and explains the various icons and menus you might see.
- *To Operate a Menu* sections show how to select and use menus including pop-ups.
- *Menu Map* shows each of the main menus (the menus that appear on the bottom of the display) and the buttons that access them.

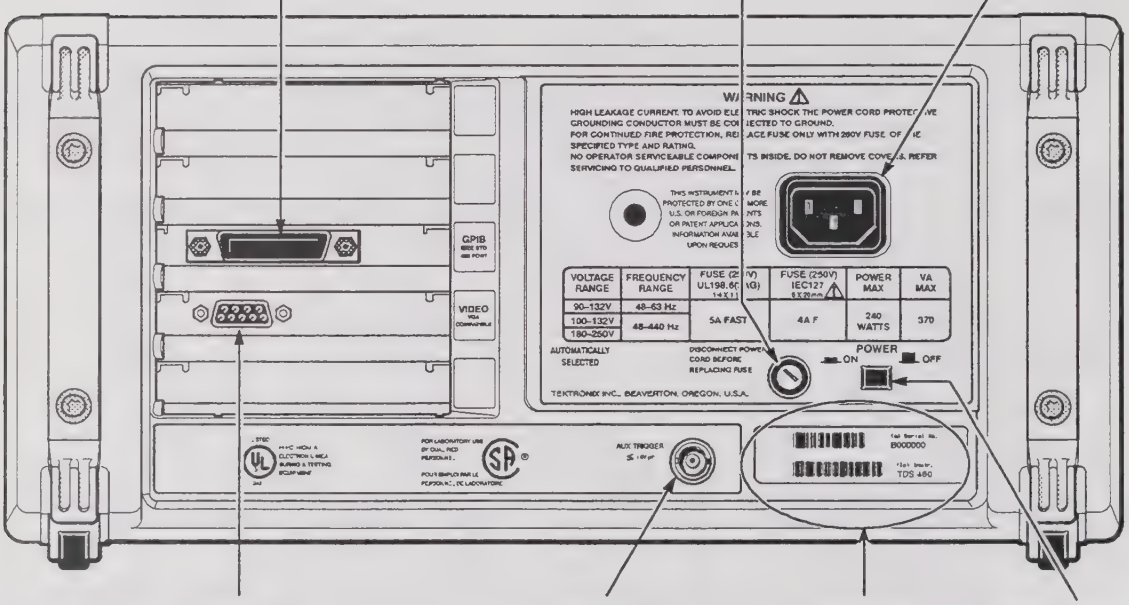
Front Panel Map – Left Side


Side Menu Buttons
Tektronix TDS 460 FOUR CHANNEL DIGITIZING OSCILLOSCOPE
350 MHz 100 MS/s
ON/ STBY
CLEAR MENU
ON/STBY Switch, page ix
Main Menu Buttons, page 3-8
CLEAR MENU Removes Menus from the Display

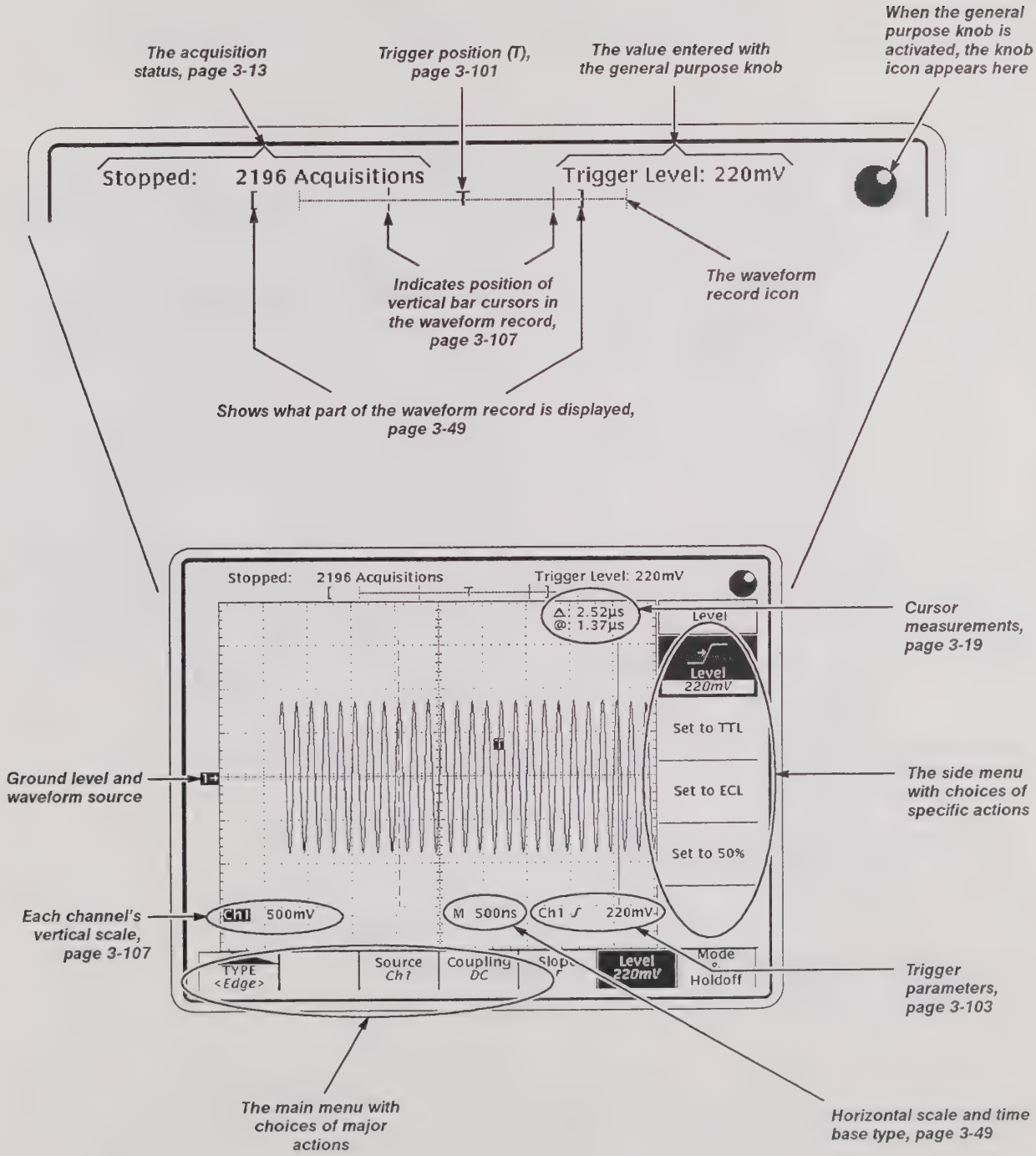
Front Panel Map – Right Side



Rear Panel Map

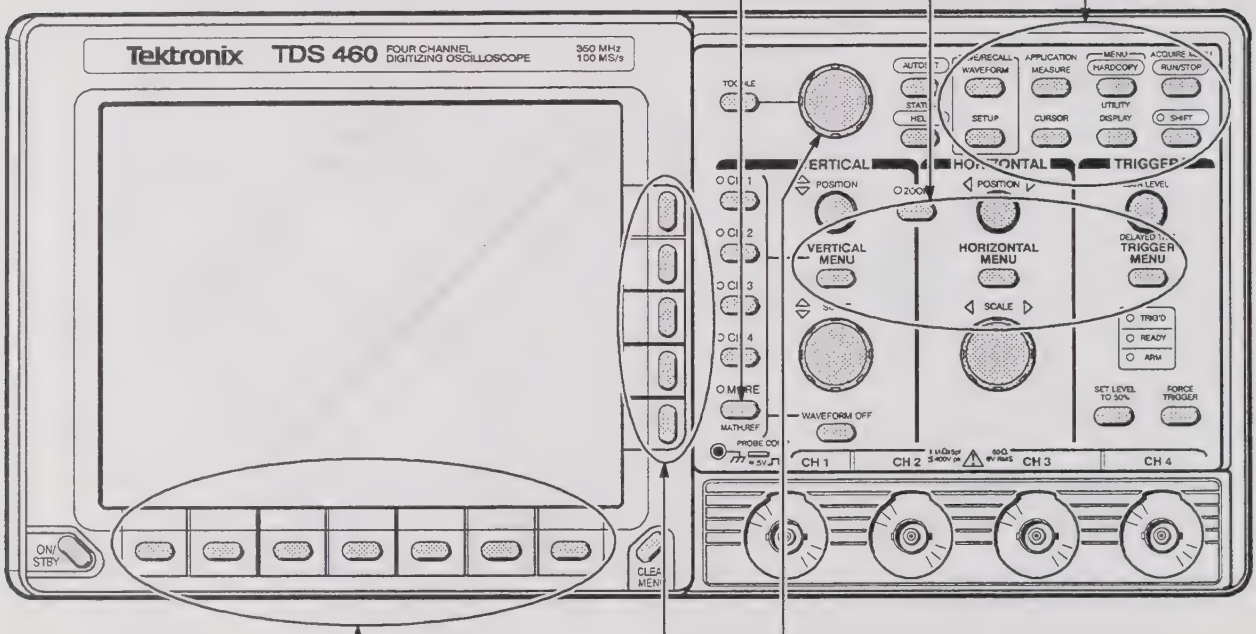


Display Map


The acquisition status, page 3-13
Trigger position (T), page 3-101
The value entered with the general purpose knob
When the general purpose knob is activated, the knob icon appears here
Stopped: 2196 Acquisitions
Trigger Level: 220mV
Indicates position of vertical bar cursors in the waveform record, page 3-107
The waveform record icon
Shows what part of the waveform record is displayed, page 3-49
Stopped: 2196 Acquisitions
Trigger Level: 220mV
Δ: 2.52µs
@: 1.37µs
Level
Level 220mV
Set to TTL
Set to ECL
Set to 50%
Cursor measurements, page 3-19
The side menu with choices of specific actions
Ground level and waveform source
Each channel's vertical scale, page 3-107
Ch1 500mV
M 500ns
Ch1 220mV
TYPE <Edge>
Source Ch1
Coupling DC
Level 220mV
Mode Holdoff
Trigger parameters, page 3-103
The main menu with choices of major actions
Horizontal scale and time base type, page 3-49

To Operate A Menu

1. Press front-panel menu button.

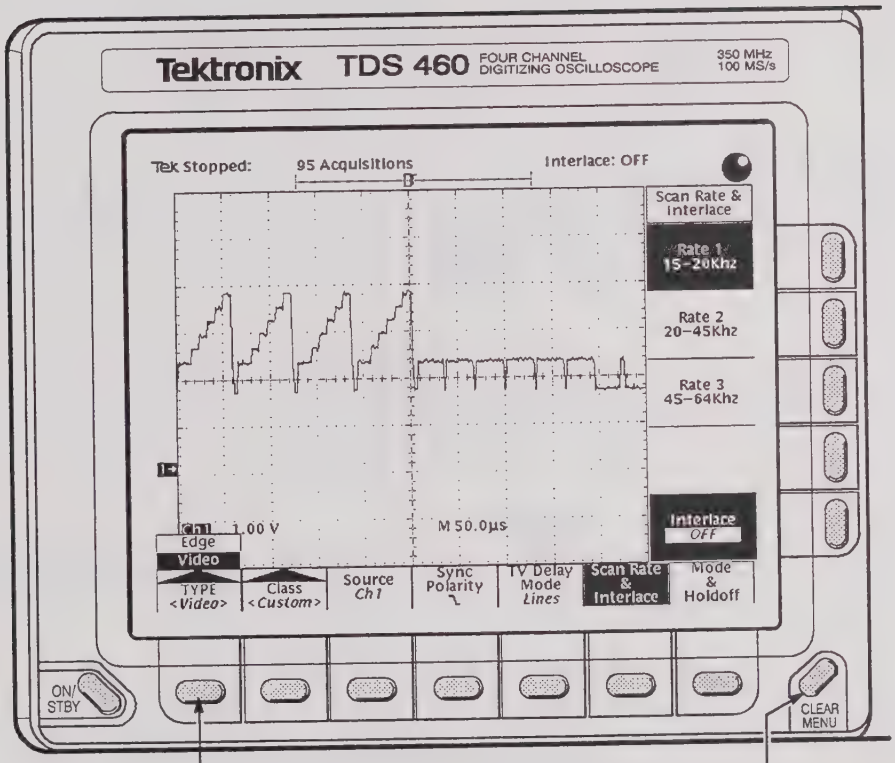


2. Press one of these buttons to select from main menu.

3. Press one of these buttons to select from side menu (if displayed).

4. If side menu item has an adjustable value (shown in reverse video), adjust it with the general purpose knob.

To Operate A Pop-Up Menu



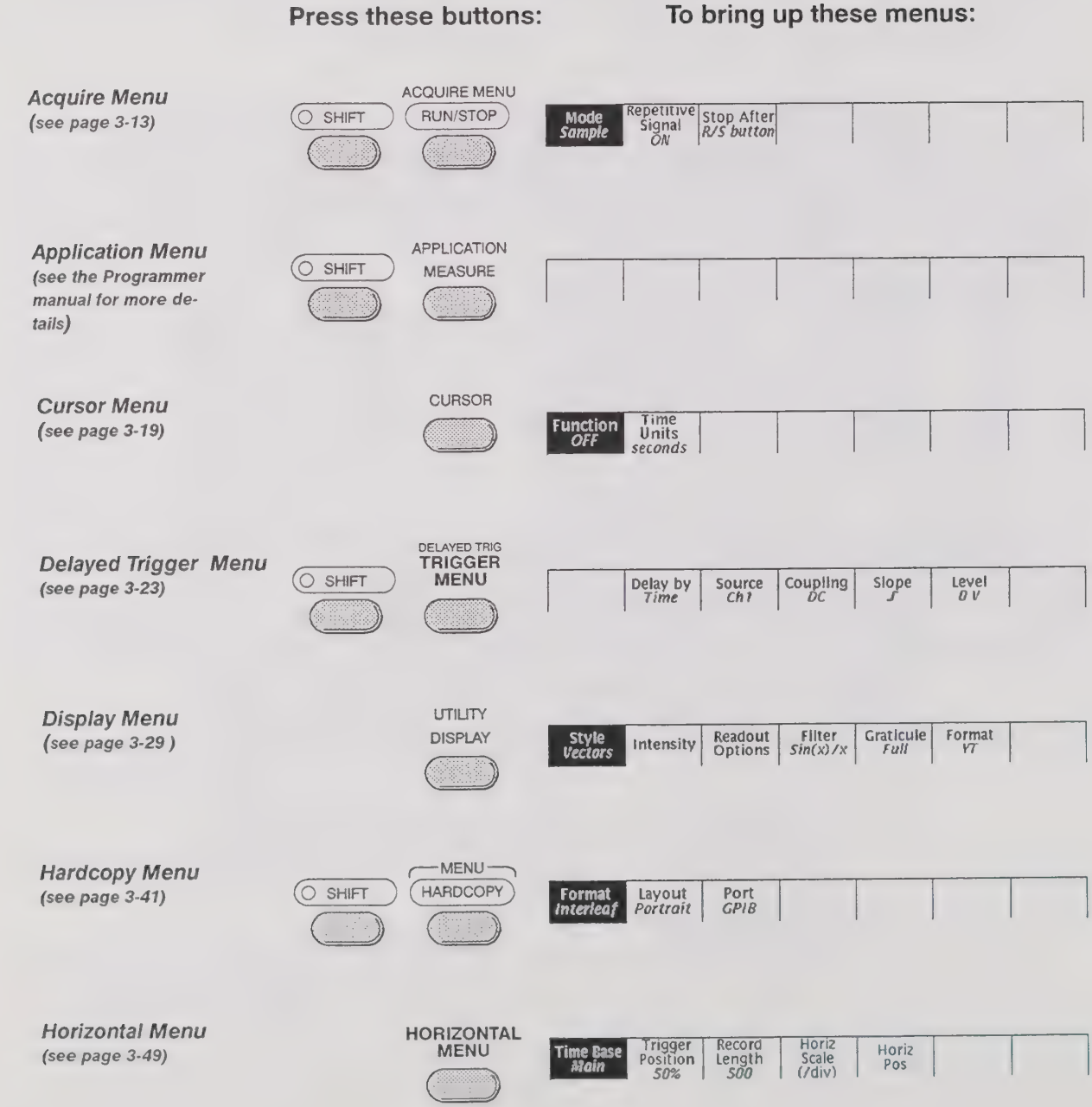
Press to display pop-ups.

Press it again to make selection.

A pop-up selection changes the other main menu titles.

Press here to remove menus from screen.

Menu Map


Press these buttons:
To bring up these menus:
Acquire Menu
(see page 3-13)
SHIFT
ACQUIRE MENU
RUN/STOP
Mode Sample
Repetitive Signal ON
Stop After R/S button
Application Menu
(see the Programmer manual for more details)
SHIFT
APPLICATION
MEASURE
Cursor Menu
(see page 3-19)
CURSOR
Function OFF
Time Units seconds
Delayed Trigger Menu
(see page 3-23)
SHIFT
DELAYED TRIG
TRIGGER MENU
Delay by Time
Source Ch1
Coupling DC
Slope
Level 0 V
Display Menu
(see page 3-29)
UTILITY
DISPLAY
Style Vectors
Intensity
Readout Options
Filter Sin(x)/x
Graticule Full
Format YT
Hardcopy Menu
(see page 3-41)
SHIFT
MENU
HARDCOPY
Format Interleaf
Layout Portrait
Port GPIB
Horizontal Menu
(see page 3-49)
HORIZONTAL MENU
Time Base Main
Trigger Position 50%
Record Length 500
Horiz Scale (/div)
Horiz Pos

Press these buttons:	To bring up these Menus:

Measure Menu
(see page 3-55)

APPLICATION MEASURE

Select Measrmnt for *Ch1*	Remove Measrmnt	**Gating** *OFF*	High-Low Setup *Histogram*	Reference Levels		

More Menu
(see page 3-117)

MORE

Math1 Ch1+Ch2	Math2 Ch1−Ch2	Math3 inv(Ch1)	Ref1	Ref2	Ref3	Ref4

Save/Recall Setup Menu
(see page 3-91)

SETUP

Save Current Setup	Recall Saved Setup	Recall Factory Setup				

Save/Recall Waveform Menu
(see page 3-93)

SAVE/RECALL WAVEFORM

Save Waveform *Math1*	Recall Waveform	Delete Refs				

Status Menu
(see page 3-99)

SHIFT + STATUS HELP

Status Snapshot
System
Trigger
Waveforms
GPIB

Trigger Menu – Edge
(see page 3-35)

DELAYED TRIG **TRIGGER MENU**

Type *<Edge>*		Source *Ch1*	Coupling *DC*	Slope *∫*	Level *0 V*	Mode & Holdoff

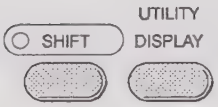
Trigger Menu – Video
(see page 3-111)

DELAYED TRIG **TRIGGER MENU**

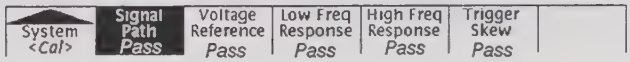
TYPE *<Video>*	Class *<Custom>*	Source *Aux*	Sync Polarity ⌝	TV Delay Mode *Lines*	**Scan Rate & Interlace**	Mode & Holdoff

Press these buttons: **To bring up these Menus:**

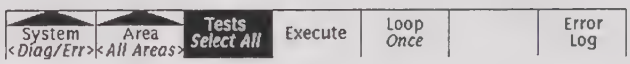
Utility Menu – I/O
(see page 3-89)



Utility Menu – Calibration
(see page A-29)

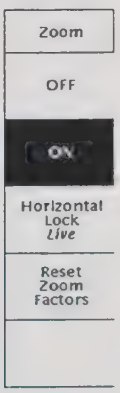


Utility Menu – Diagnostics
(see page A-29)



Vertical Channel Menu
(see page 3-107)

Zoom Menu
(see page 3-119)



Acquisition Modes

The acquisition system has several options for converting analog data into digital form. The Acquisition menu lets you determine the acquisition mode, whether or not to permit equivalent time sampling, and how to start and stop acquisitions.

Acquisition Readout

The Acquisition readout at the top of the display (Figure 3-1) shows the state of the acquisition system (running or stopped). The "running" state shows the sample speed and acquisition mode. The "stopped" state shows the number of acquisitions acquired since the last stop or major change.

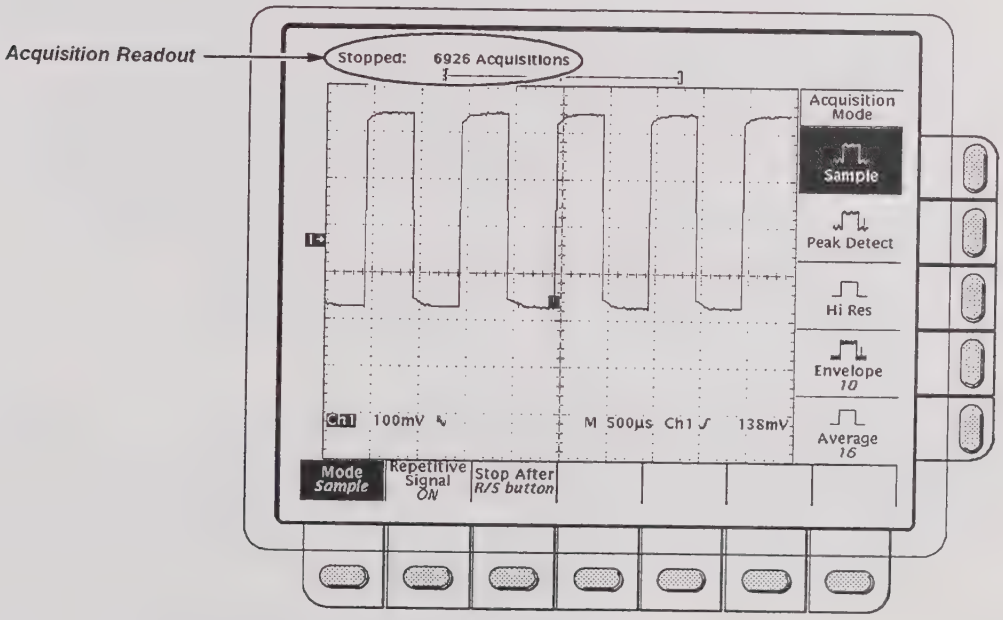


Figure 3-1: Acquisition Readout

Operation

To bring up the acquisition menu (Figure 3-2) press the **ACQUIRE MENU** button (**SHIFT** and then **RUN/STOP**).

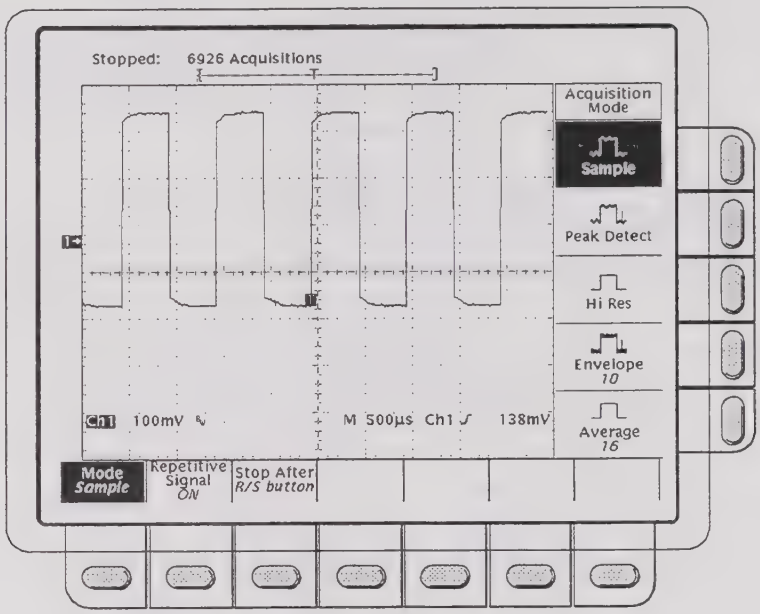


Figure 3-2: Acquire Menu

Acquisition Mode

The **Mode** option lets you choose how the digitizing oscilloscope will create points in the waveform record.

☐ **Step 1:** On the Acquire menu, press **Mode** from the main menu.

☐ **Step 2:** From the side menu select either **Sample**, **Peak Detect**, **Hi Res**, **Envelope,** or **Average**.

- **Sample** mode (default mode) saves the first sample (out of perhaps many) during each acquisition interval.
- **Peak Detect** mode saves the minimum and maximum samples over two acquisition intervals.
- **Hi Res** mode averages all samples in an acquisition interval to create a record point.
- **Envelope** uses the highest and lowest samples across several waveform records.
- **Average** calculates the average value for each record point over many waveform records.

NOTE

If you selected the longest record length available in the Horizontal menu, then you cannot select hi res or average as your acquisition mode. Because these modes have twice the resolution of other modes (16-bit as opposed to 8-bit), if they were selected along with the longest record length the oscilloscope would run out of memory.

When you select **Envelope** or **Average**, you can enter the number of waveform records using the general purpose knob. If you want to enter a large number using the general purpose knob, press the **SHIFT** button before turning the knob. When the light next to the **SHIFT** button is on and the display says ***Coarse Knobs*** in the upper right corner, the general purpose knob speeds up significantly.

Repetitive Signal

Using the **Repetitive Signal** menu item, you can limit the digitizing oscilloscope to real-time sampling or let it choose between real-time or equivalent-time sampling. See *Acquisition* on page 2-13 for details about sampling.

☐ **Step 1:** Press **Repetitive Signal** from the main menu.

☐ **Step 2:** Press **ON (Enable ET)** from the side menu if you want to use both the real time and the equivalent time features of the digitizing oscilloscope. The digitizing oscilloscope automatically switches to equivalent-time sampling when the horizontal scale is faster than 500 ns, otherwise it uses real-time sampling.

or

Press **OFF (Real Time Only)** from the side menu. That selection limits the digitizing oscilloscope to real time sampling. If the time base is faster than 500 ns, the oscilloscope will use the interpolation method selected in the Display menu to fill in the missing record points. That is, it will use either the linear or sin(x)/x interpolation algorithm.

Stop After

You can choose to acquire exactly one waveform sequence or to acquire waveforms continuously under manual control.

☐ **Step 1:** Press **Stop After** from the main menu (see Figure 3-3).

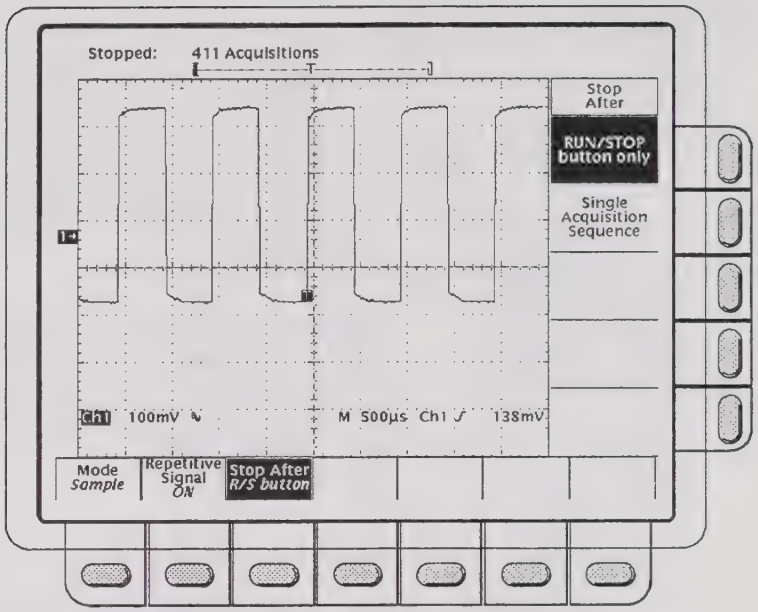


Figure 3-3: Acquire Menu—Stop After

☐ **Step 2:** Press **RUN/STOP button only** from the side menu if you want to start or stop acquisitions by toggling the **RUN/STOP** button. Pressing the **RUN/STOP** button once will stop the acquisitions. The upper left-hand corner in the display will say **Stopped** and the number of acquisitions. If you press the button again, the digitizing oscilloscope will resume taking acquisitions.

or

Press **Single Acquisition Sequence** from the side menu. That selection lets you run a single sequence of acquisitions by pressing the **RUN/STOP** button. In sample, peak detect, or hi res mode, the instrument will acquire a waveform record with the first valid trigger event and stop.

In envelope or average mode, the digitizing oscilloscope will acquire the specified number of acquisitions to complete the averaging or enveloping task.

If the oscilloscope is in equivalent-time mode and you select **Single Acquisition Sequence**, it will continue to recognize trigger events and acquire samples until the waveform record is filled.

For More Information

See *Acquisition*, on page 2-13.

Autoset

The autoset function lets you quickly obtain and display a stable waveform of usable size. Autoset automatically sets up the front panel controls based on the signal's characteristics. That is much faster and easier than a manual control-by-control setup.

Autoset makes adjustments in these areas:

- Acquisition
- Display
- Horizontal
- Trigger
- Vertical

Operation

☐ **Step 1:** Press the Channel Selection button (such as **CH 1**) corresponding to your input channel to make it active.

☐ **Step 2:** Press **AUTOSET**.

If you use autoset when one or more channels are displayed, the digitizing oscilloscope selects the lowest numbered channel for horizontal scaling and triggering. Vertically, all channels in use are individually scaled.

If you use autoset when no channels are displayed, the digitizing oscilloscope will turn on channel one (**CH 1**) and scale it.

Autoset Defaults

Table 3-1 on the following page lists the autoset defaults.

Table 3-1: Autoset Defaults

Control	Changed by Autoset to
Selected channel	Numerically lowest of the displayed channels
Acquire Mode	Sample
Acquire Repetitive Signal	On
Acquire Stop After	RUN/STOP button only
Display Style	Vectors
Display Intensity—Overall	If less than 50%, set to 75%
Display Format	YT
Horizontal Position	Centered within the graticule window
Horizontal Scale	As determined by the signal frequency
Horizontal Time Base	Main Only
Horizontal Record Length	Unchanged
Input Coupling	Unchanged
Trigger Position	Unchanged
Trigger Type	Edge
Trigger Source	Numerically lowest of the displayed channels
Trigger Level	Midpoint of data for the trigger source
Trigger Slope	Positive
Trigger Coupling	DC
Trigger Holdoff	1
Vertical Scale	As determined by the signal level
Vertical Coupling	DC unless AC was previously set. AC remains unchanged.
Vertical Bandwidth	Full
Vertical Offset	0 volts
Zoom	Off

Cursor Measurements

Use the cursors to measure the difference (either in time or voltage) between two locations in a waveform record.

Cursors are made up of two markers that you position with the general purpose knob. You can move only one cursor at a time. The non-selected cursor is a dashed line on the display. You use the **TOGGLE** button to change which cursor is selected. As you position the cursors, readouts on the display report measurement information.

There are two cursor types: *horizontal bar* and *vertical bar* (Figure 3-4). The vertical bar cursors measure time or frequency between two points on the waveform record, and the horizontal bar cursors measure voltage.

Horizontal Bar Cursors *Vertical Bar Cursors*

Figure 3-4: Cursor Types

Cursor Readouts

The cursor readout shows the absolute location of the selected cursor and the difference between the selected and non-selected cursor. The readouts differ depending on whether you are using **H Bars** or **V Bars**.

- **H Bars:** the value after Δ shows the voltage difference between the cursors. The value after @ shows the voltage of the selected cursor relative to ground (see Figure 3-5).
- **V Bars:** the value after Δ shows the time (or, optionally, frequency) difference between the cursors. The value after @ shows the time (frequency) of the selected cursor relative to the trigger (see Figure 3-6).

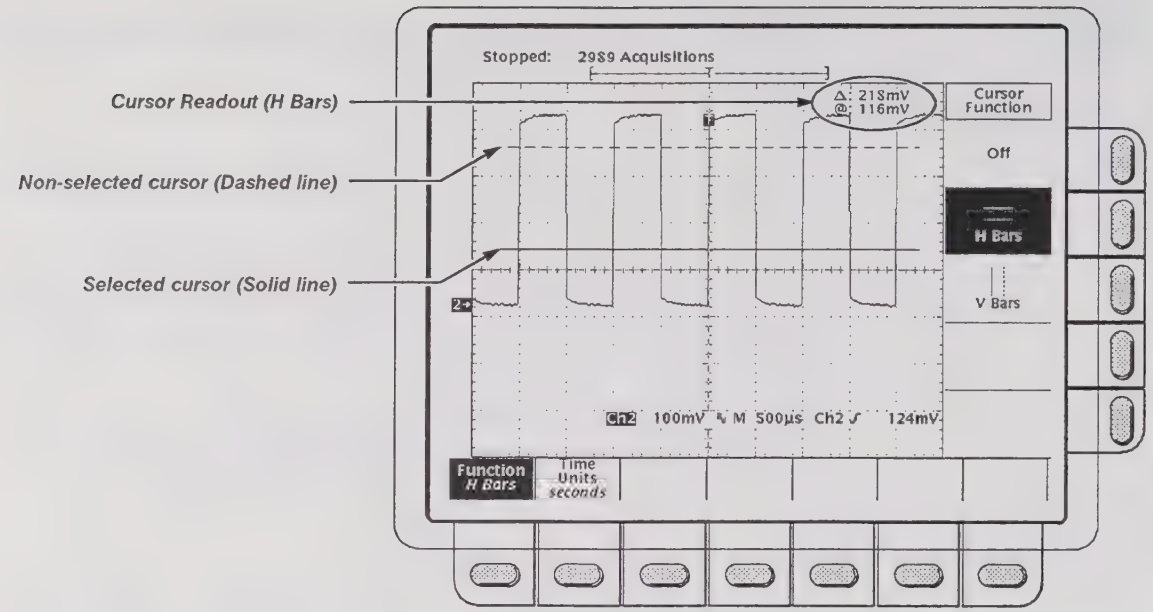


Figure 3-5: H Bars Cursor Menu and Readouts

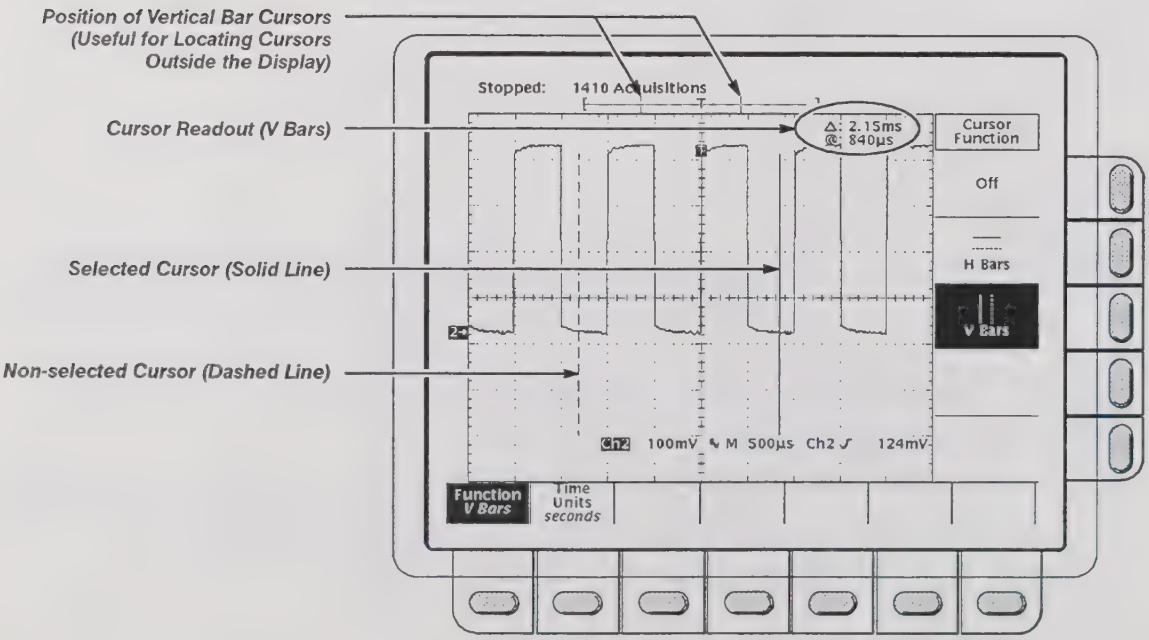


Figure 3-6: V Bars Cursor Menu and Readouts

Operation

To take cursor measurements press the **CURSOR** button to display the Cursor menu (Figure 3-6).

Function

You can select the type of cursors you want using the **Function** menu item.

☐ **Step 1:** Select **Function** from the main menu.

☐ **Step 2:** From the side menu you can choose between:

- **H Bars** to display horizontal bars
- **V Bars** to display vertical bars.
- **Off** to remove any existing cursor bars

☐ **Step 3:** Use the general purpose knob to move the selected (active) cursor. Use the **TOGGLE** button to change which cursor is active and moves. A solid line indicates the active cursor and a dashed line the inactive cursor.

Time Units

You can choose to display vertical bar cursor results in units of time or frequency (see Figure 3-7).

☐ **Step 1:** From the Cursor main menu, select the **Time Units** item.

☐ **Step 2:** From the side menu, select **seconds** or **1/seconds (Hz)**.

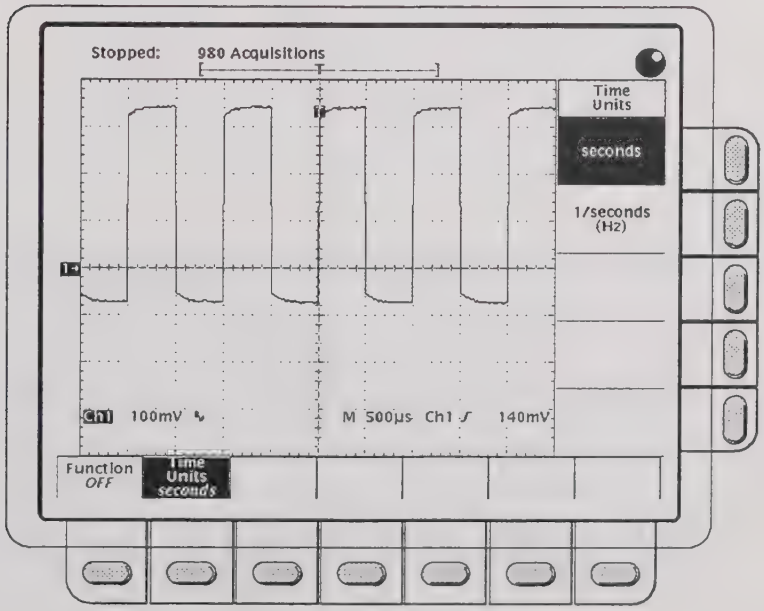


Figure 3-7: Cursor Menu—Time Units

Cursor Speed

You can change the cursors speed by pressing **SHIFT** before turning the general purpose knob. The cursor moves faster when the **SHIFT** button is lighted and the display says ***Coarse Knobs*** in the upper right corner. This feature is particularly useful when moving V Bar cursors through waveforms with long record lengths.

For More Information

See *Measurements*, on page 2-25.

Delayed Triggering

The TDS 400 Series oscilloscopes provide a main time base and a delayed time base. The delayed time base, like the main time base, requires a trigger signal and an input source dedicated to that signal. You can only use delay with the edge trigger. See *Triggering* on page 2-5 for more information about delay.

If you want to delay the video trigger, use the Video Trigger menu delay option. See *Video Triggering* on page 3-111 for more information.

There are two different ways to delay the edge trigger: *delayed runs after main* and *delayed triggerable*. Only the delayed triggerable mode uses the delayed time base.

Operation

You use the Horizontal menu to select and define either delayed runs after main or delayed triggerable. Delayed triggerable, however, requires further selections in the Delayed Trigger menu.

Delayed Runs After Main

Delayed runs after main waits for a main trigger, then waits a user-defined time, and then the digitizing oscilloscope starts acquiring (Figure 3-8). You select and define that delay in the Horizontal menu.

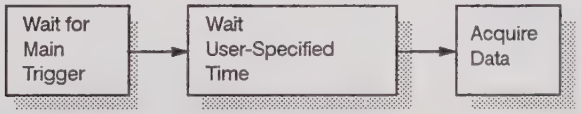


Figure 3-8: Delayed Runs After Main

- ☐ **Step 1:** Press the **HORIZONTAL MENU** button to bring up the Horizontal menu (Figure 3-9).
- ☐ **Step 2:** Press **Time Base** from the main menu.
- ☐ **Step 3:** Select **Delayed Only** to view the delayed time base.
- ☐ **Step 4:** Choose the **Delayed Runs After Main** item from the side menu. Use the general purpose knob to set the delay time.

By pressing **Intensified**, you can display an intensified zone that shows where the delayed trigger record length occurs relative to the main trigger.

To learn how to define the intensity level of the normal and intensified waveform, see *Display Modes* on page 3-29. The start of the intensified zone corresponds to the start of the delayed trigger. The end of the zone corresponds to the end of the record.

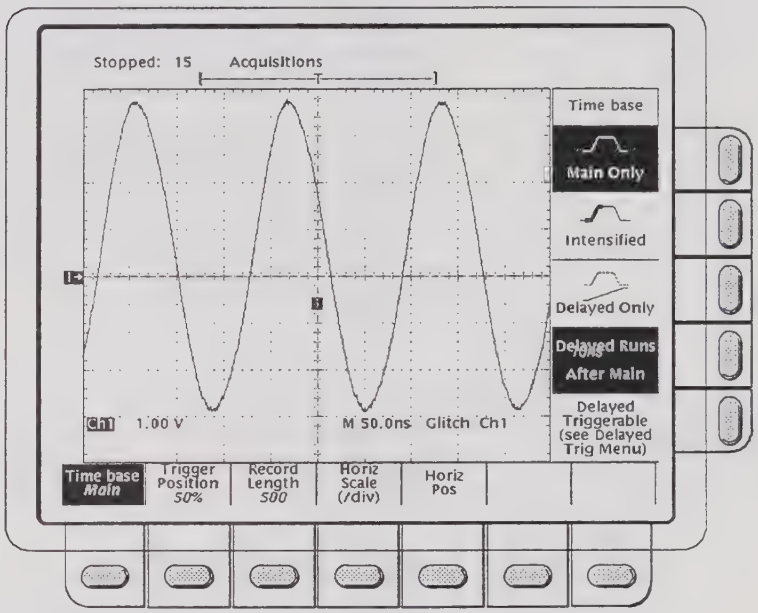


Figure 3-9: Horizontal Menu—Time Base

Delayed Triggerable

Delayed triggerable waits for a main trigger, then waits a user-defined time or number–1 of delayed trigger events, and then looks for the next delayed trigger event (Figure 3-10). You need to use both the Horizontal and Delayed Trigger menus to define the delayed trigger event.

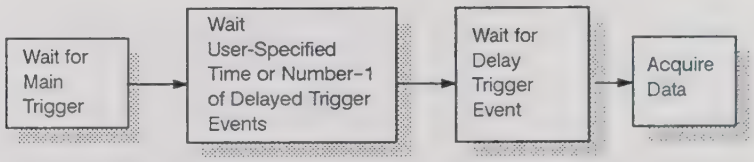

Wait for Main Trigger
Wait User-Specified Time or Number–1 of Delayed Trigger Events
Wait for Delay Trigger Event
Acquire Data

Figure 3-10: Delayed Triggerable

☐ **Step 1:** Press the **HORIZONTAL MENU** button to bring up the Horizontal menu (see Figure 3-9).

☐ **Step 2:** Press **Time Base** from the main menu.

☐ **Step 3:** Select **Delayed Only** to view the delayed time base.

☐ **Step 4:** Choose the **Delayed Triggerable** item from the side menu.

By pressing **Intensified**, you can display an intensified zone that shows where the delayed trigger record length may occur relative to the main trigger.

To learn how to define the intensity level of the normal and intensified waveform, see *Display Modes* on page 3-29. The start of the intensified zone corresponds to the possible start point of the delayed trigger. The end of the zone corresponds to the end of the record.

Now you need to bring up the Delayed Trigger menu so you can define the delayed trigger event.

☐ **Step 5:** Press the **DELAYED TRIG** button (**SHIFT** and **TRIGGER MENU** buttons) to bring up the Delayed Trigger menu (Figure 3-11).

☐ **Step 6:** Press the main menu **Delay by** and select either **Delay by Time** or **Delay by Events**.

☐ **Step 7:** Enter the the delay time or events using the general purpose knob. If you want to enter a large number with the general purpose knob, press the **SHIFT** button before turning the knob. When the light the **SHIFT** button is on and the display says ***Coarse Knobs*** in the upper right corner, the general purpose knob speeds up significantly.

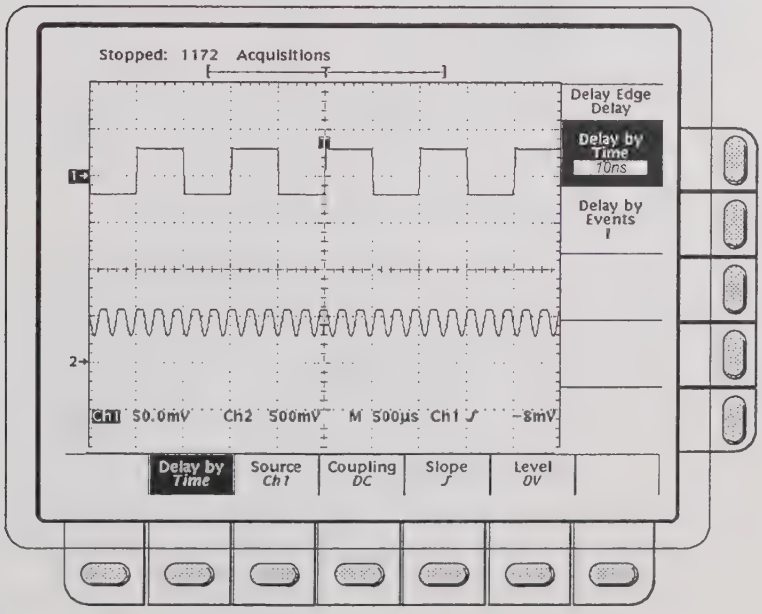


Figure 3-11: Delayed Trigger Menu

NOTE

The delay time in the delay runs after main mode is independent from the delay time in the delayed triggerable mode. These times do not track each other.

The **Source** menu option lets you select which input will be the delayed trigger source.

☐ **Step 1:** Press the main menu **Source** to select the delayed trigger source.

☐ **Step 2:** From the side menu, select **Ch1**, **Ch2**, **Ch3**, **Ch4**, or **Auxiliary**.

Use the **Coupling** menu selection to define how the input signal will be coupled to the delayed trigger.

☐ **Step 1:** Press the main menu **Coupling** (Figure 3-12).

☐ **Step 2:** From the side menu, choose **DC**, **AC**, **HF Rej**, **LF Rej**, or **Noise Rej**. For descriptions of these coupling types, see *Triggering* on page 2-5.

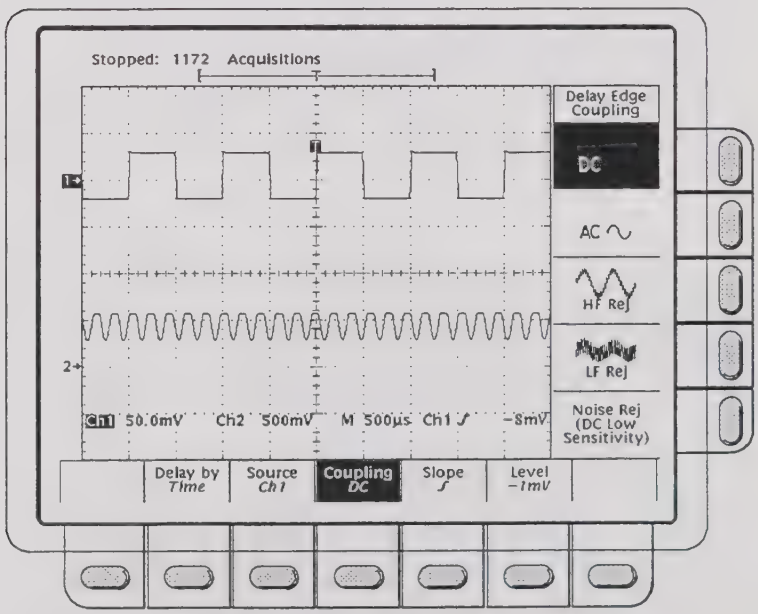


Figure 3-12: Delayed Trigger Menu—Coupling

Slope lets you select the slope that the delayed trigger will occur on.

☐ **Step 1:** Press the main menu **Slope**.

☐ **Step 2:** Choose between the rising edge and falling edge slopes.

The **Level** menu item presents several ways to define the delayed trigger level.

☐ **Step 1:** Select the main menu **Level** item (Figure 3-13).

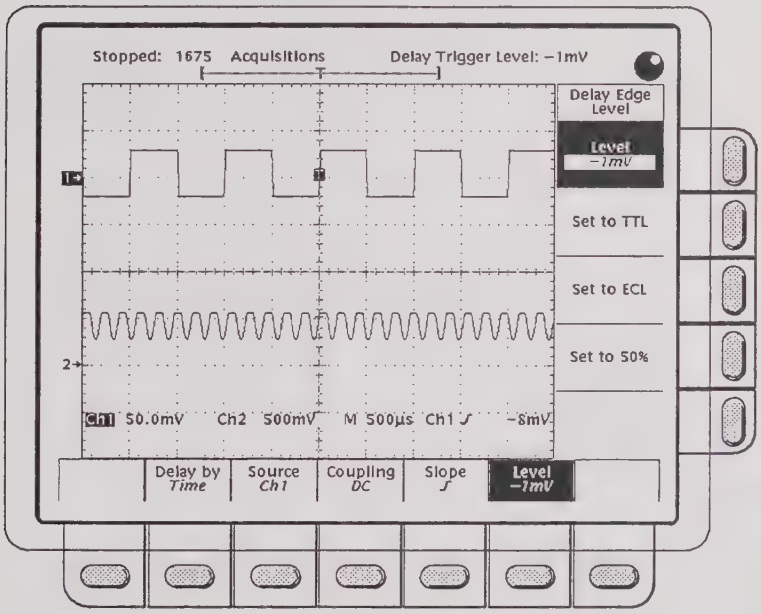


Figure 3-13: Delayed Trigger Menu—Level

☐ **Step 2:** Select one of the side menu items. There are several ways to set the trigger level:

- **Level** lets you enter the delayed trigger level using the general purpose knob.
- **Set to TTL** fixes the trigger level at +1.4 V.
- **Set to ECL** fixes the trigger level at −1.3 V.

NOTE

When you set the volts/div smaller than 200 mV, the oscilloscope reduces the ***Set to TTL*** *or* ***Set to ECL*** *trigger levels below standard TTL and ECL levels. That happens because the trigger level range is fixed at ± 12 divisions from the center. As you decrease the volts/div, those ± 12 divisions cover a smaller range of voltages. At 100 mV (the next smaller setting after 200 mV) the trigger range is ± 1.2 V which is smaller than the typical TTL (+ 1.4 V) or ECL (−1.3 V) level.*

- **Set to 50%** fixes the delayed trigger level to 50% of the peak-to-peak value of the delayed trigger source signal.

NOTE

When setting the delayed trigger level to 50% be sure you've first selected ***Delayed Triggerable*** *from the Horizontal menu, otherwise the main trigger level will be set to 50%.*

For More Information

See *Triggering*, on page 2-5.

Display Modes

The digitizing oscilloscope can display waveform records in different ways. The Display menu lets you adjust the oscilloscope's display style, intensity level, graticule, and format.

Operation

Press the **DISPLAY** button to show the Display menu.

Display Style

☐ **Step 1:** Select the **Style** menu item to select the display style for the waveform record (Figure 3-14).

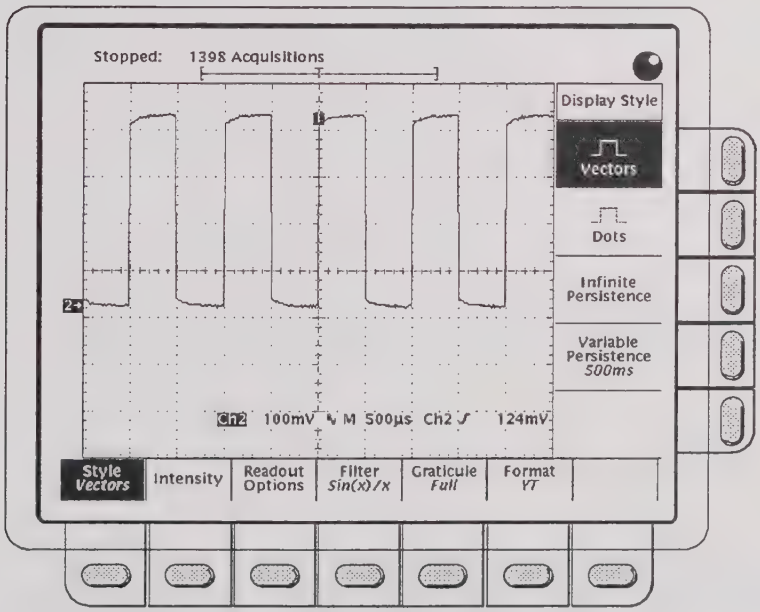


Figure 3-14: Display Menu—Style

☐ **Step 2:** On the side menu choose between **Vectors**, or **Dots**, and **Infinite Persistence** or **Variable Persistence**.

- **Dots** display waveform record points as dots.
- **Vectors** has the display draw vectors (lines) between the record points. That does not affect the value of the waveform record points.
- **Variable Persistence** lets the record points accumulate on screen over many acquisitions and remain displayed only for a specific time interval. In that mode, the display behaves like an analog oscilloscope's screen. You enter the time for that option with the general purpose knob.
- **Infinite Persistence** lets the record points accumulate until you change some control (such as scale factor) causing the display to be erased.

Intensity

Intensity lets you set overall, text/graticule, and waveform intensity (brightness) levels. You can also set the contrast intensity of the delay portion of a waveform.

☐ **Step 1:** Select the **Intensity** menu item (Figure 3-15).

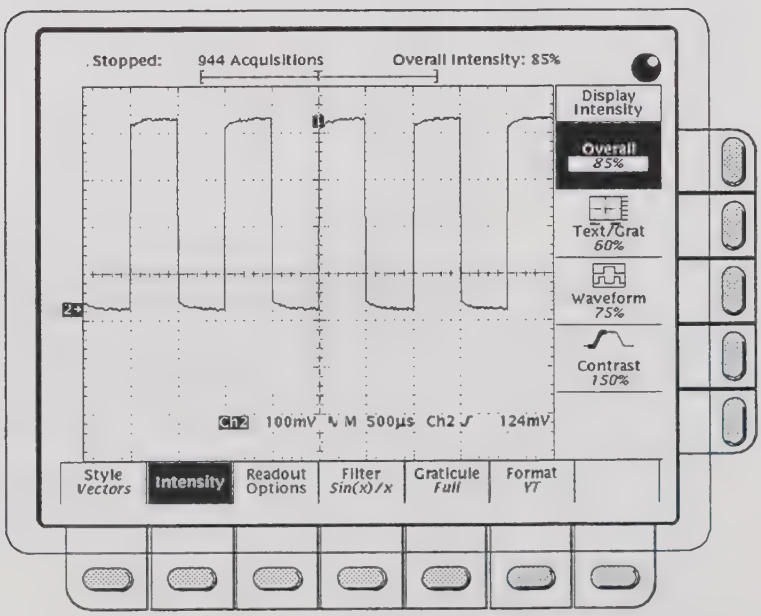


Figure 3-15: Display Menu—Intensity

☐ **Step 2:** Then select **Overall**, **Text/Grat**, **Waveform**, or **Contrast** from the side menu. Enter the intensity percentage values with the general purpose knob.

All intensity adjustments operate over a range from 20% (close to fully off) to 100% (fully bright).

Contrast operates over a range from 100% (no contrast) to 250% (intensified portion at full brightness).

NOTE

If the contrast is set to 100%, you won't be able to distinguish the intensified portion from the rest of the waveform because both are the same brightness.

Display Readout

Readout options control whether the trigger indicator appears on the display.

☐ **Step 1:** Press **Readout** from the main menu.

☐ **Step 2:** Then toggle the side menu **Display 'T' @ Trigger Point** to select whether or not to display 'T' indicating the trigger point. You can select **ON** or **OFF**.

Filter Type

The display filter types are sin(x)/x interpolation and linear interpolation. For more information see the discussion of interpolation in the *Concepts* section on page 2-14.

☐ **Step 1:** Press **Filter** from the main menu.

☐ **Step 2:** Select either **Sin(x)/x Interpolation** or **Linear Interpolation** from the side menu.

Linear Interpolation computes record points between actual acquired samples by using a straight line fit. It assumes all the interpolated points fall in their appropriate point in time on that straight line. This is useful for many linear waveforms like pulse trains.

Sin(x)/x Interpolation computes record points using a curve fit between the actual values acquired. It assumes all the interpolated points fall along that curve. This is particularly useful when acquiring more rounded waveforms like sine waves. Actually, it is appropriate for general use, although it may introduce some overshoot or undershoot in signals with fast rise times.

Graticule Type

☐ **Step 1:** To change the graticule, select the **Graticule** menu item (Figure 3-16).

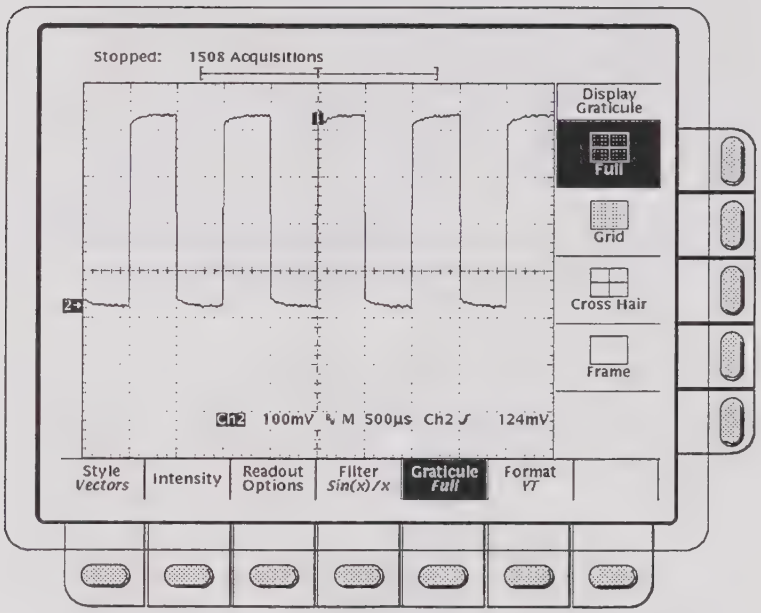
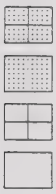


Figure 3-16: Display Menu—Graticule

☐ **Step 2:** Select **Full**, **Grid**, **Cross Hair**, or **Frame** from the side menu.



- **Full** provides a grid, cross hairs and a frame.
- **Grid** displays a frame and a grid.
- **Cross Hair** provides cross hairs and a frame.
- **Frame** displays just a frame.

Format

There are two kinds of format: YT and XY.

YT is the conventional oscilloscope display format. It shows a signal voltage (the vertical axis) as it varies over time (the horizontal axis).

XY format compares the voltage levels of two waveform records point by point. That is, the digitizing oscilloscope displays a graph of the voltage of one waveform record against the voltage of another waveform record. That mode is particularly useful for studying phase relationships.

To set the display axis format:

☐ **Step 1:** Select the main menu **Format** item (Figure 3-17).

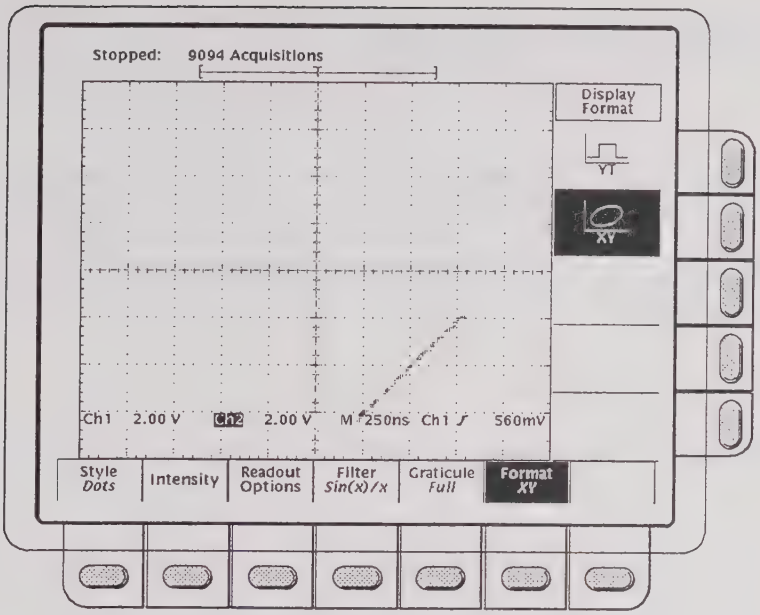


Figure 3-17: Display Menu—Format

☐ **Step 2:** Choose **XY** or **YT** from the side menu.

When you choose the XY mode, the input you have selected is assigned to the X-axis and the digitizing oscilloscope automatically chooses the Y-axis input (see Table 3-2).

Table 3-2: XY Format Pairs

X-Axis Channel (User Selectable)	Y-Axis Channel (Fixed)
Ch 1	Ch 2
Ch 3	Ch 4

For example, if you press the **CH 1** button, the digitizing oscilloscope will display a graph of Channel 1's voltage levels on the X-axis against channel 2's voltage levels on the Y-axis. That will occur whether or not you are displaying channel 2's waveform in YT format. If you sometime later press the **WAVEFORM OFF** button for either channel 1 or 2, the digitizing oscilloscope will delete the XY graph of channel 1 versus channel 2.

Since the selecting **YT** or **XY** only affects the display, the horizontal and vertical scale and position knobs and menus control the same parameters regardless of the mode selected. Specifically, in XY mode, the horizontal scale will continue to control the time base and the horizontal position will continue to control which portion of the waveforms are displayed.

XY format is a dot-only display, although it can have persistence. The **Vector** style selection has no effect when you select XY format.

You cannot display Math waveforms in XY format. They will disappear from the display when you select XY.

For More Information

See *Acquisition* on page 2-13.

Edge Triggering

An *edge trigger* event occurs when the trigger source passes through a specified voltage level in a specified direction (the trigger slope). You will likely use edge triggering for most of your measurements.

You can select the edge source, coupling, slope, level, and mode (auto or normal).

Edge Trigger Readouts

At the bottom of the display, the Trigger readout shows some of the trigger's key parameters (Figure 3-18).

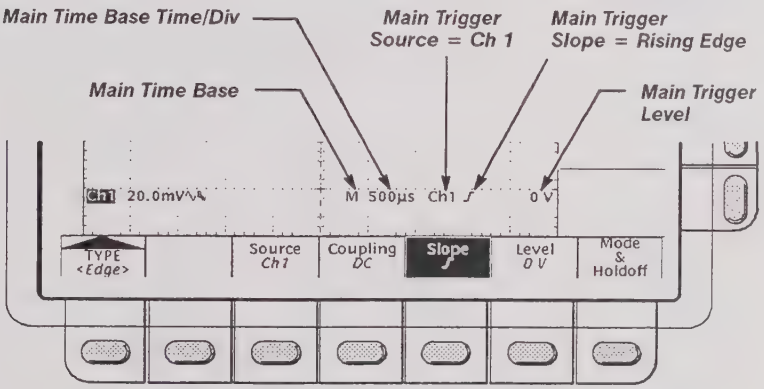


Figure 3-18: Edge Trigger Readouts

Operation

The Edge Trigger menus let you select the the source, coupling, slope, trigger level, mode, and holdoff.

To bring up the Edge Trigger menu:

☐ **Step 1:** Press the **TRIGGER MENU** button to bring up the Main Trigger menu.

☐ **Step 2:** Press the **Type** main menu button until you select **Edge** from the pop-up menu (see Figure 3-19). If you do not have the video option, edge will be your only choice for trigger type.

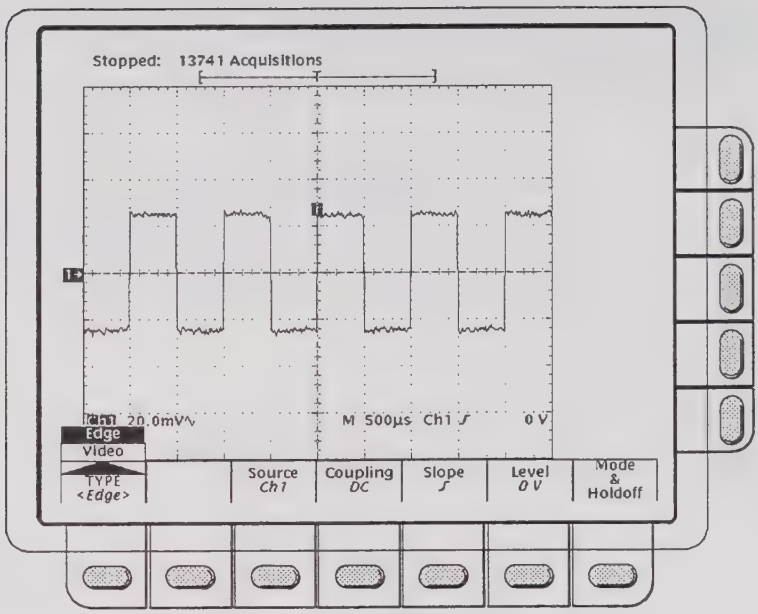


Figure 3-19: Main Trigger Menu—Edge Type

Source

You need to select which source you want for the trigger.

☐ **Step 1:** Choose the edge source by selecting the main menu **Source** item.

☐ **Step 2:** Select one the six available sources in the side menu (**Ch1**, **Ch2**, **Ch3**, **Ch4**, **AC Line**, or **Auxiliary**).

Coupling

This option lets you select the coupling you want.

☐ **Step 1:** Press the main menu **Coupling.**

☐ **Step 2:** From the side menu, choose **DC**, **AC**, **HF Rej**, **LF Rej**, or **Noise Rej** (Figure 3-20).

DC

- **DC** passes all of the input signal. In other words, it passes both AC and DC components to the trigger circuit.

AC ∿

- **AC** passes only the alternating components of an input signal (above 30 Hz). It removes the trigger signal's DC components.

In addition, the trigger system also has *high frequency rejection, low frequency rejection* and *noise rejection*. These eliminate specific frequency components (noise) from the trigger signal.

- **HF Rej** removes the high frequency portion of the triggering signal. That allows only the low frequency components to pass on to the triggering system to start an acquisition. On the digitizing oscilloscope, high frequency rejection attenuates signals above 30 kHz.

- **LF Rej** does the opposite of high frequency rejection. Low frequency rejection attenuates signals below 80 kHz.
- **Noise Rej** provides low DC sensitivity. It requires additional signal amplitude for stable triggering, reducing the chance of falsely triggering on noise.

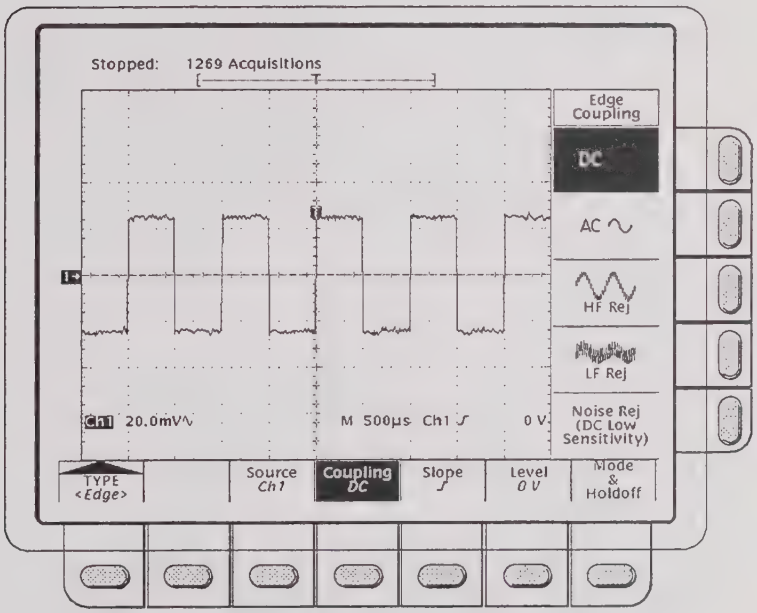


Figure 3-20: Edge Trigger Menu—Coupling

Slope

You can select the slope that the edge trigger will occur on.

☐ **Step 1:** Press the main menu **Slope** to select the slope that the edge trigger will have.

☐ **Step 2:** Alternatives for slope are the rising and falling edges.

Level

☐ **Step 1:** Press the main menu **Level** to bring up a side menu of alternative ways to enter the trigger level (Figure 3-21).

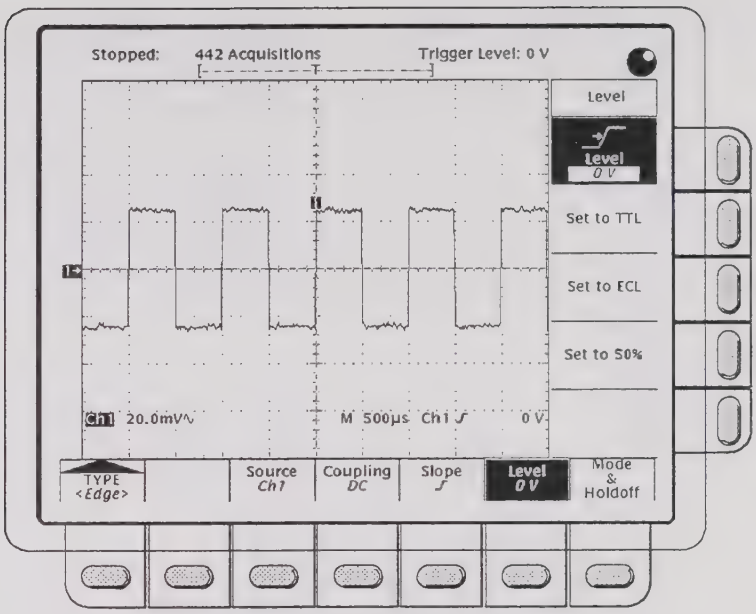


Figure 3-21: Edge Trigger Menu—Level

☐ **Step 2:** Select one of the side menu items. There are several ways to set the trigger level:

- **Level** lets you enter the trigger level using the general purpose knob. If you want to enter a large number using the general purpose knob, press the **SHIFT** button before turning the knob. When the light next to the **SHIFT** button is on and the display says **Coarse Knobs** in the upper right corner, the general purpose knob speeds up significantly.
- **Set to TTL** fixes the trigger level at +1.4 V.
- **Set to ECL** fixes the trigger level at –1.3 V.

NOTE

When you set the volts/div smaller than 200 mV, the oscilloscope reduces the ***Set to TTL*** *or* ***Set to ECL*** *trigger levels below standard TTL and ECL levels. That happens because the trigger level range is fixed at ±12 divisions from the center. As you decrease the volts/div, those ±12 divisions cover a smaller range of voltages. At 100 mV (the next smaller setting after 200 mV) the trigger range is ±1.2 V, which is smaller than the typical TTL (+1.4 V) or ECL (–1.3 V) level.*

- **Set to 50%** fixes the trigger level to 50% of the peak-to-peak value of the trigger source signal. You can also set the trigger level to 50% by pressing the **SET LEVEL TO 50%** button.

Mode & Holdoff

You can change the holdoff time and select the trigger mode using this menu item. See Triggering on page 2-5 for more details on trigger mode and holdoff.

☐ **Step 1:** Press the **Mode & Holdoff** in the main menu.

☐ **Step 2:** To set the mode, press either **Auto** or **Normal** (see Figure 3-22).

- In **Auto** mode the oscilloscope acquires a waveform after a specific time has elapsed even if a trigger doesn't occur. The amount of time the oscilloscope waits depends on the time base setting.
- In **Normal** mode the oscilloscope acquires a waveform only if there is a valid trigger.

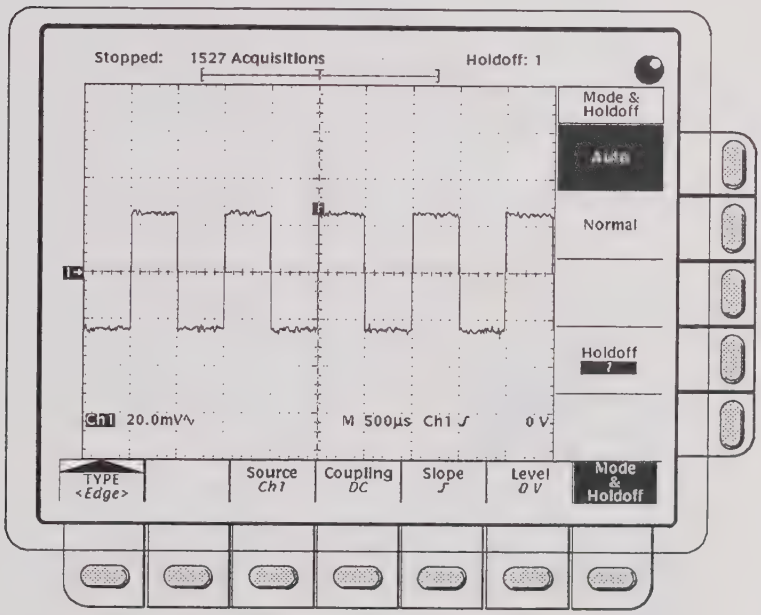


Figure 3-22: Edge Trigger Menu—Mode & Holdoff

☐ **Step 3:** To change the holdoff time, select the **Holdoff** side menu item. Enter the value in % using the general purpose knob. If you want to enter a large number using the general purpose knob, press the **SHIFT** button before turning the knob. When the light next to the **SHIFT** button is on and the display says **Coarse Knobs** in the upper right corner, the general purpose knob speeds up significantly.

Holdoff is automatically reset to 0% when you change the main time base time/division setting. However, it is not reset if you change the delayed time base time/division (that is, when the time base setting in the Horizontal menu is **Intensified** or **Delayed Only**).

For More Information

See *Triggering*, on page 2-5.

Hardcopy

You can get a copy of the digitizing oscilloscope's display by using the hardcopy feature. Depending on the output format you select, you create either an image or a plot. Images are direct bit map representations of the digitizing oscilloscope display. Plots are vector (plotted) representations of the display.

Operation

Before you make a hardcopy, you need to set up communications and hardcopy parameters.

Setting Communication Parameters

Do the following to set up the communication parameters:

☐ **Step 1:** Press the **UTILITY** button (**SHIFT** and then **DISPLAY**) to show the Utility menu.

☐ **Step 2:** Select **I/O** from the **System** main menu pop-up (see Figure 3-23).

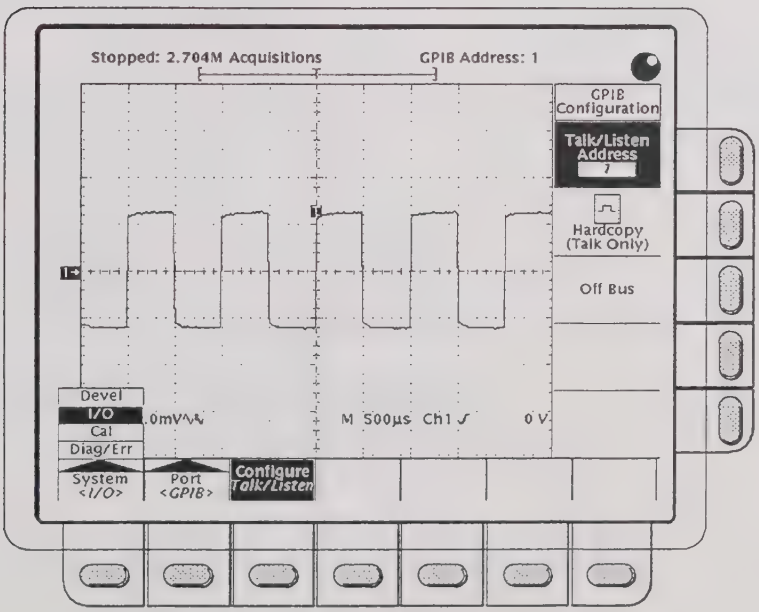


Figure 3-23: Utility Menu – System I/O

☐ **Step 3:** Choose **Configure** from the main menu.

☐ **Step 4:** Select the **Hardcopy (Talk Only)** option from the side menu.

Setting Hardcopy Parameters

You can specify the hardcopy's format, layout, and type of port using the hardcopy menu. Press the **HARDCOPY MENU** button (**SHIFT** and then **HARDCOPY**) to bring up the Hardcopy menu.

The **Format** main menu item lets you change the way the oscilloscope formats the hardcopy data.

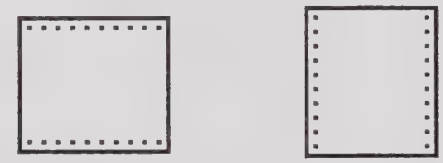
☐ **Step 1:** Press the main menu **Format** button.

☐ **Step 2:** You can choose **Thinkjet**, **Deskjet**, **Laserjet**, **Epson**, **Interleaf**, **EPS Image** (Postscript) or **HPGL** from the side menu item.

The **Layout** main menu item lets you specify whether to print the hardcopy in landscape or portrait format.

☐ **Step 1:** Press the **Layout** main menu button.

☐ **Step 2:** Select the appropriate side menu item. You can choose **Landscape** or **Portrait** (see Figure 3-24).



Landscape Format *Portrait Format*

Figure 3-24: Hardcopy Formats

The **Port** main menu item lets you specify the output channel to send your hardcopy through. The only choice is **GPIB**.

Printing the Hardcopy

To print a copy of the display, simply press the **HARDCOPY** button. If for some reason you want to stop the hardcopy process, press the **HARDCOPY** button on the front panel again.

Connection Strategies

The digitizing oscilloscope's ability to print a copy of its display in many formats (Thinkjet, Deskjet, Laserjet, Epson, Interleaf, EPS Image (Postscript), and HPGL) gives you flexibility in choosing a hardcopy device. It also makes it easier for you to read TDS screen copies into a desktop publishing system.

However, since the TDS has only a GPIB interface port and many hardcopy devices have only RS-232 or Centronics ports, you need a connection strategy for sending the hardcopy data from the digitizing oscilloscope to the printer or plotter. Three such strategies exist. You can:

- use a printer/plotter with a GPIB connector,
- use a GPIB-to-Centronics or GPIB-to-RS232 converter box, or
- send the data to a computer with both GPIB and RS-232 or Centronics ports.

Using a GPIB-Based Hardcopy Device

You can connect the digitizing oscilloscope directly to a GPIB-based hardcopy device (see Figure 3-25). An example of a GPIB hardcopy device is the Tektronix HC100 Plotter.

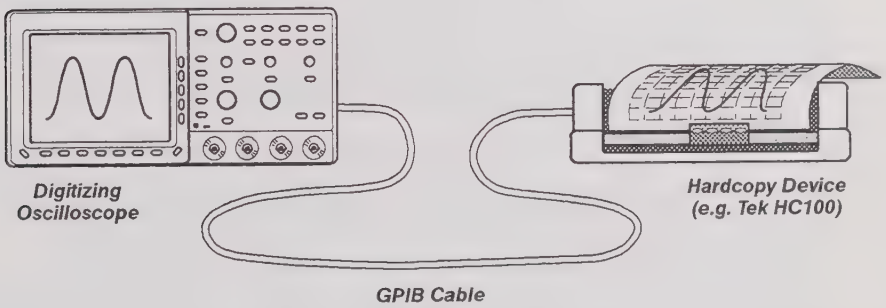


Figure 3-25: Connecting the TDS Directly to the Hardcopy Device

Using a GPIB-to-Centronics or GPIB-to-RS232 Converter

You can put a GPIB-to-Centronics or GPIB-to-RS232 interface converter box between the TDS and the RS-232 or Centronics hardcopy device (see Figure 3-26). For example, a National Instruments GPIB-PRL (a GPIB-to-Centronics converter) will permit you to make screen prints on a Tektronix HC200 Dot Matrix printer with just a Centronics port.

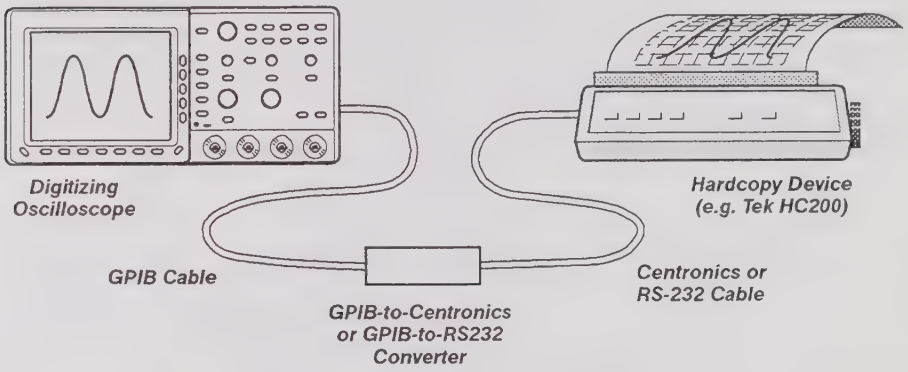


Figure 3-26: Connecting the TDS and Hardcopy Device Via a Converter

Using a Controller

You can put a controller with two ports between the TDS and the hardcopy device (see Figure 3-27). One port must be a GPIB and the other must be either an RS-232 or a Centronics port.

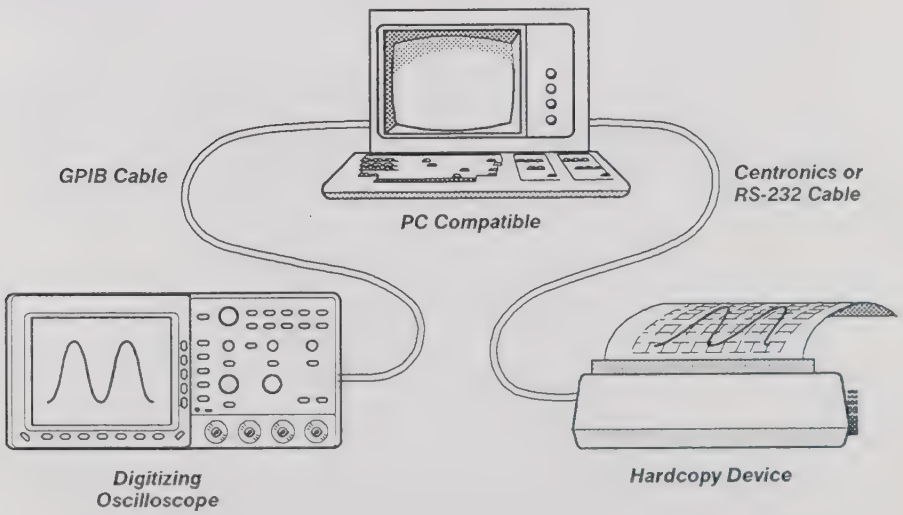


Figure 3-27: Connecting the TDS and Hardcopy Device Via a PC

If your controller is PC-compatible and it uses the Tektronix GURU or S3FG210 (National Instruments GPIB-PCII/IIA) GPIB package, you can operate this setup as follows:

- ☐ **Step 1:** Use the MS-DOS *cd* command to move to the directory that holds the software that came with your GPIB board. For example, if you installed the software in the GPIB-PC directory, type: **cd GPIB-PC**
- ☐ **Step 2:** Run the IBIC program that came with your GPIB board. Type: **IBIC**
- ☐ **Step 3:** Type: **IBFIND DEV1**
  where "DEV1" is the name for the digitizing oscilloscope you defined using the IBCONF.EXE program that came with the GPIB board. Note: if you defined another name then, of course, use it instead of "DEV1". Also, remember that the digitizing oscilloscope's device address as set with the IBCONF.EXE program should match the address set in the TDS' Utility menu (typically, use "1").
- ☐ **Step 4:** Type: **IBWRT "HARDCOPY START"**
  Be sure the TDS Utility menu is set to **Talk/Listen** and not **Hardcopy (Talk Only)** or you will get an error message at this step. Setting the TDS Utility menu was described in the start of this Hardcopy section under the heading *Setting Communication Parameters*.
- ☐ **Step 5:** Type: **IBRDF <Filename>**
  where <Filename> is a valid DOS file name you want to call your hardcopy information. It should be ≤ 8 characters long with up to a 3 character extension. For example, you could type *"ibrdf screen1"*.
- ☐ **Step 6:** Exit the IBIC program by typing: **EXIT**
- ☐ **Step 7:** Type: **COPY <Filename> <Output port>**
  where <Filename> is the name you defined in step 5 and <Output port> is the PC output port your hardcopy device is connected to (such as LPT1 or LPT2). Copy the data from your file to your hardcopy device. First, ensure your printer or plotter is properly attached to your PC. Then copy the file. For example, if your file is called *screen1* and your printer is attached to the *lpt1* parallel port, type *"copy screen1 lpt1:"*.

Your hardcopy device should now print a picture of the TDS screen.

For More Information

See *Save and Document*, on page 2-29.

See *Remote Communications*, on page 2-31.

See *Remote Communication*, on page 3-89.

Help

The on-line help system provides brief information about each of the digitizing oscilloscope's controls.

Operation

To use the on-line help system:

☐ **Step 1:** Press the **HELP** button to provide on-screen information on any front panel button, knob or menu item (see Figure 3-28).

When you press that button, the instrument changes mode to support on-line help. Press the **HELP** button again to return to regular operating mode. Whenever the oscilloscope is in help mode, pressing any button (except **HELP** or **SHIFT**), turning any knob, or pressing any menu item displays help text on the screen that discusses that control.

The menu selections that were displayed when **HELP** was first pressed remain on the screen. On-line help is available for each menu selection displayed at the time the **HELP** button was first pressed. If you are in help mode and want to see help on selections from non-displayed menus, you first exit help mode, display the menu you want information on, and press the **HELP** button again to re-enter help mode.

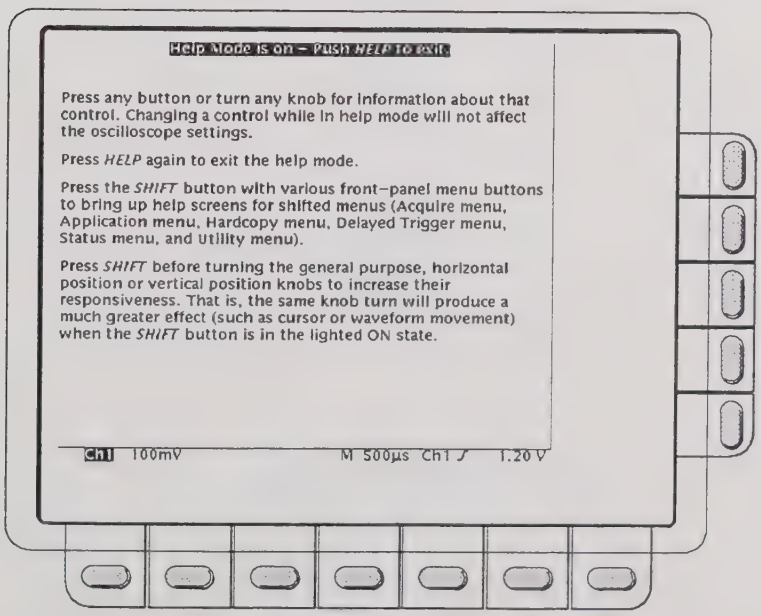

Help Mode is on – Push HELP to exit.
Press any button or turn any knob for information about that control. Changing a control while in help mode will not affect the oscilloscope settings.
Press HELP again to exit the help mode.
Press the SHIFT button with various front-panel menu buttons to bring up help screens for shifted menus (Acquire menu, Application menu, Hardcopy menu, Delayed Trigger menu, Status menu, and Utility menu).
Press SHIFT before turning the general purpose, horizontal position or vertical position knobs to increase their responsiveness. That is, the same knob turn will produce a much greater effect (such as cursor or waveform movement) when the SHIFT button is in the lighted ON state.
Ch1 100mV
M 500µs Ch1 ƒ 1.20 V

Figure 3-28: Initial Help Screen

Horizontal Control

You can control the horizontal part of the display (the time base) using the horizontal menu and knobs.

Horizontal Knobs

By changing the horizontal scale, you can focus on a particular portion of a waveform. By adjusting the horizontal position, you can move the waveform right or left to see different portions of it. That is particularly useful when you're using larger record sizes and can't view the entire waveform on one screen.

To change the horizontal scale and position, use the horizontal **POSITION** and horizontal **SCALE** knobs (see Figure 3-29). These knobs manage the time base and horizontal waveform positioning on the screen.

When you use either the horizontal **SCALE** or **POSITION** knobs, you will affect all the waveform records displayed. If you want the **POSITION** knob to move faster, press the **SHIFT** button. When the light next to the **SHIFT** button is on and the display says **Coarse Knobs** in the upper right corner, the **POSITION** knob speeds up significantly.

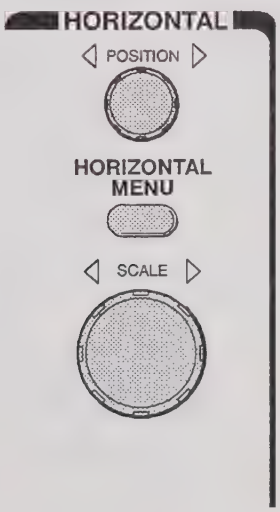


Figure 3-29: Horizontal Controls

Horizontal Readouts

At the top of the display, the *Record View* shows the size and location of the waveform record and the location of the trigger relative to the display (see Figure 3-30).

The *Time Base readout* at the lower right of the display shows the time/division settings and the time base (main or delayed) being referred to (see Figure 3-30).

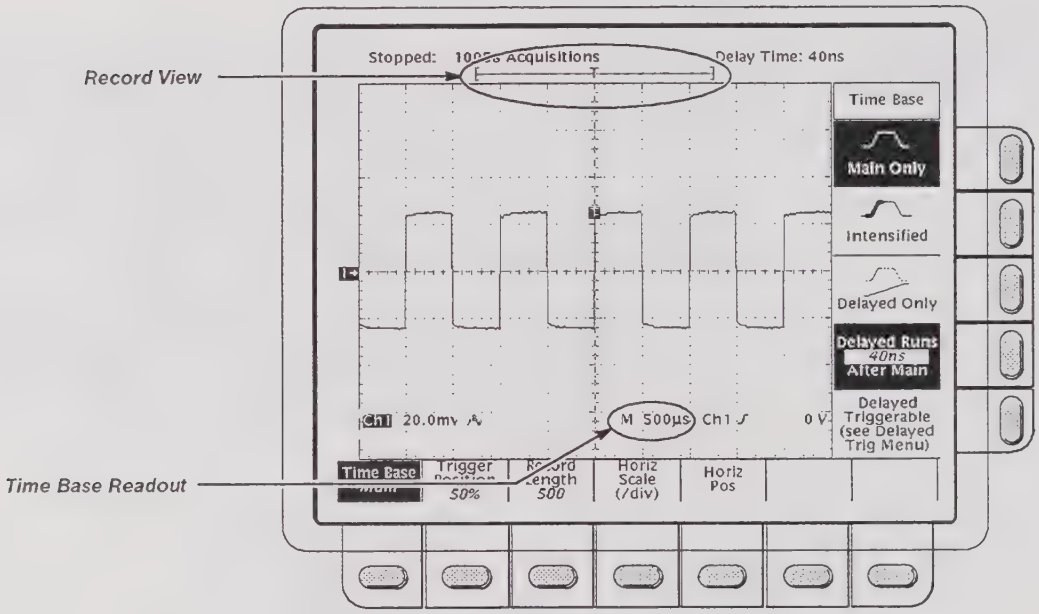


Figure 3-30: Record View and Time Base Readouts

Horizontal Menu

The Horizontal menu lets you select either a main or delayed view of the time base for acquisitions. It also lets you set the record length, set the trigger position, and change the position or scale.

Press the **HORIZONTAL MENU** button to bring up the Horizontal menu (Figure 3-31).

Main and Delayed Time Base

You can select between the Main and Delayed views of the time base.

☐ **Step 1:** Press the **Time Base** (see Figure 3-31).

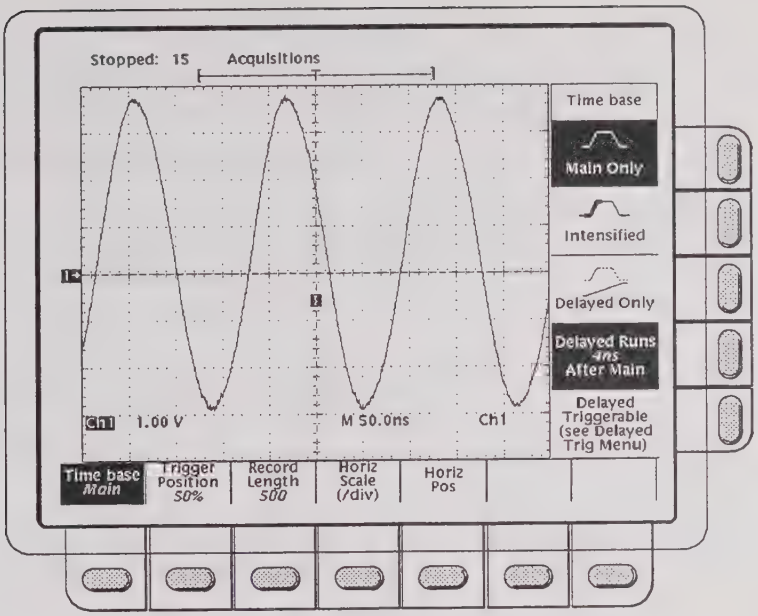


Figure 3-31: Horizontal Menu—Time Base

☐ **Step 2:** Depending on what you want displayed, choose between **Main Only**, **Intensified**, or **Delay Only**.

By pressing **Intensified**, you display an intensified zone that shows where the delayed trigger record length could occur relative to the main trigger. The start of the intensified zone corresponds to the possible start point of the delayed trigger. The end of the zone corresponds to the end of the waveform record.

To learn how to change the intensity of the normal and intensified waveform, see *Display Modes* on page 3-29.

You also can select **Delayed Runs After Main** or **Delayed Triggerable**. For more information on how to use the these two menu items, see *Delayed Triggering* on page 3-23.

Trigger Position

You can define how much of the record will be pretrigger and how much posttrigger information using the **Trigger Position** menu item.

☐ **Step 1:** Press **Trigger Position** from the main menu (Figure 3-32).

☐ **Step 2:** You can set the trigger position by entering a value into the side menu **Pretrigger** item using the general purpose knob. Or you can select preset values using the **Set to 10%**, **Set to 50%**, and **Set to 90%** items from the side menu.

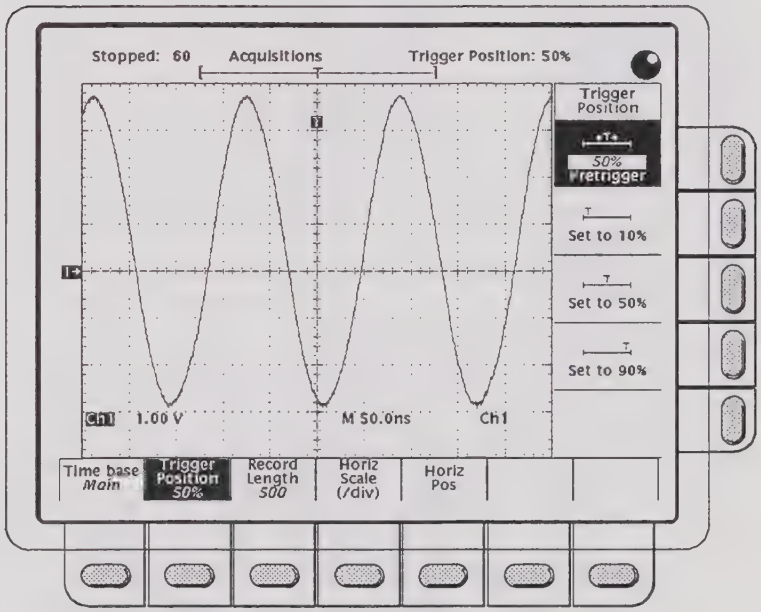


Figure 3-32: Horizontal Menu—Trigger Position

Record Length

To set the waveform record length, select the **Record Length** item in the Horizontal main menu. The side menu lists various discrete record length choices.

NOTE

*If you have option 1M (record length of 30,000) and you have chosen **Hi res** or **Average** as your acquisition mode, then you cannot select the largest record length available. These two modes have double the resolution compared to other modes (16-bit as opposed to 8-bit), so the oscilloscope would run out of memory if the maximum record length was selected.*

Horizontal Scale

You can change the horizontal scale (time per division) numerically in the menu instead of using the Horizontal **SCALE** knob.

- ☐ **Step 1:** Press the **Horiz Scale**.
- ☐ **Step 2:** On the side menu, press either **Main Scale** or **Delayed Scale** and change the scale values with the general purpose knob.

Horizontal Position

You can set the horizontal position to specific values in the menu instead of using the Horizontal **POSITION** knob.

- ☐ **Step 1:** Select the **Horiz Pos** main menu item.
- ☐ **Step 2:** On the side menu, press the **Set to 10%**, **Set to 50%** or **Set to 90%** buttons to choose how much of the waveform will be displayed to the left of the display center.

For More Information

See *Scaling and Positioning Waveforms,* on page 2-21.

See *Delayed Triggering*, on page 3-23.

Measurement System

There are various ways to measure properties of waveforms. You can use graticule, cursor, or automatic measurements. The cursors and graticules are described elsewhere. (See *Cursor Measurements* on page 3-19 and *Measurements* on page 2-25.) This section describes *automatic measurements*. These are generally more accurate and quicker than, for example, manually counting graticule divisions. The oscilloscope will continuously update and display these measurements.

Automatic measurements calculate waveform parameters from acquired data. Measurements are made on the entire record (where relevant), not just the portion displayed on the screen.

The TDS 400 Series Digitizing Oscilloscopes provide you with 22 automatic measurements (see Table 3-3).

Definitions

The following are brief definitions of the automated measurements in the digitizing oscilloscope (for more details see *Appendix D: Algorithms,* page A-75).

Measurements are performed over the entire waveform record or the region specified by the vertical cursors, if gated measurements have been requested. See page 3-60 for a discussion of gated measurements.

Table 3-3: Measurement Definitions

Name	Definition
Amplitude	Voltage measurement. The high value less the low value measured over the entire waveform or gated region. *Amplitude = High – Low*
Burst Width	Timing measurement. The duration of a burst. Measured over the entire waveform or gated region.
Cycle Mean	Voltage measurement. The arithmetic mean over the first cycle in the waveform, or the first cycle in the gated region.
Cycle RMS	Voltage measurement. The true Root Mean Square voltage over the first cycle in the waveform, or the first cycle in the gated region.
Delay	Timing measurement. The time between the MidRef crossings of two different traces, or the gated region of the traces.

Table 3-3: Measurement Definitions (Cont.)

Name	Definition
Fall Time	Timing measurement. Time taken for the falling edge of the first pulse in the waveform or gated region to fall from a High Ref value (default = 90%) to a Low Ref value (default = 10%) of its final value.
Frequency	Timing measurement for the first cycle in the waveform or gated region. The reciprocal of the period. Measured in Hertz (Hz) where 1 Hz = 1 cycle per second.
High	The value used as 100% whenever High Ref, Mid Ref, and Low Ref values are needed (as in fall time and rise time measurements). Calculated using either the min/max or the histogram method. The *min/max* method uses the maximum value found. The *histogram* method uses the most common value found above the mid point. Measured over the entire waveform or gated region.
Low	The value used as 0% whenever High Ref, Mid Ref, and Low Ref values are needed as in fall time and rise time measurements. May be calculated using either the min/max or the histogram method. With the min/max method it is the minimum value found. With the histogram method, it refers to the most common value found below the mid point. Measured over the entire waveform or gated region.
Maximum	Voltage measurement. The maximum amplitude. Typically the most positive peak voltage. Measured over the entire waveform or gated region.
Mean	Voltage measurement. The arithmetic mean over the entire waveform or gated region.
Minimum	Voltage measurement. The minimum amplitude. Typically the most negative peak voltage. Measured over the entire waveform or gated region.
Negative Duty Cycle	Timing measurement of the first cycle in the waveform or gated region. The ratio of the negative pulse width to the signal period expressed as a percentage. $NegativeDutyCycle = \frac{NegativeWidth}{Period} \times 100\%$
Negative Overshoot	Voltage measurement. Measured over the entire waveform or gated region. $NegativeOvershoot = \frac{Low - Min}{Amplitude} \times 100\%$

Table 3-3: Measurement Definitions (Cont.)

Name	Definition
Negative Width	Timing measurement of the first pulse in the waveform or gated region. The distance (time) between MidRef (default 50%) amplitude points of a negative pulse.
Peak to Peak	Voltage measurement. The absolute difference between the maximum and minimum amplitude in the entire waveform or gated region.
Period	Timing measurement. Time it takes for the first complete signal cycle to happen in the waveform or gated region. The reciprocal of frequency. Measured in seconds.
Positive Duty Cycle	Timing measurement of the first cycle in the waveform or gated region. The ratio of the positive pulse width to the signal period expressed as a percentage. $$PositiveDutyCycle = \frac{PositiveWidth}{Period} \times 100\%$$
Positive Overshoot	Voltage measurement over the entire waveform or gated region. $$PositiveOvershoot = \frac{Max - High}{Amplitude} \times 100\%$$
Positive Width	Timing measurement of the first pulse in the waveform or gated region. The distance (time) between MidRef (default 50%) amplitude points of a positive pulse.
Rise time	Timing measurement. Time taken for the leading edge of the first pulse in the waveform or gated region to rise from a Low Ref value (default = 10%) to a High Ref value (default = 90%) of its final value.
RMS	Voltage measurement. The true Root Mean Square voltage over the entire waveform or gated region.

Measurement Display

The readout area for measurements is on the right side of the waveform window. You can display and continuously update as many as four measurements at any one time.

When menus are displayed, the readouts appear in the graticule area. If the menu area is empty, then the readouts are displayed to the far right (see Figure 3-33).

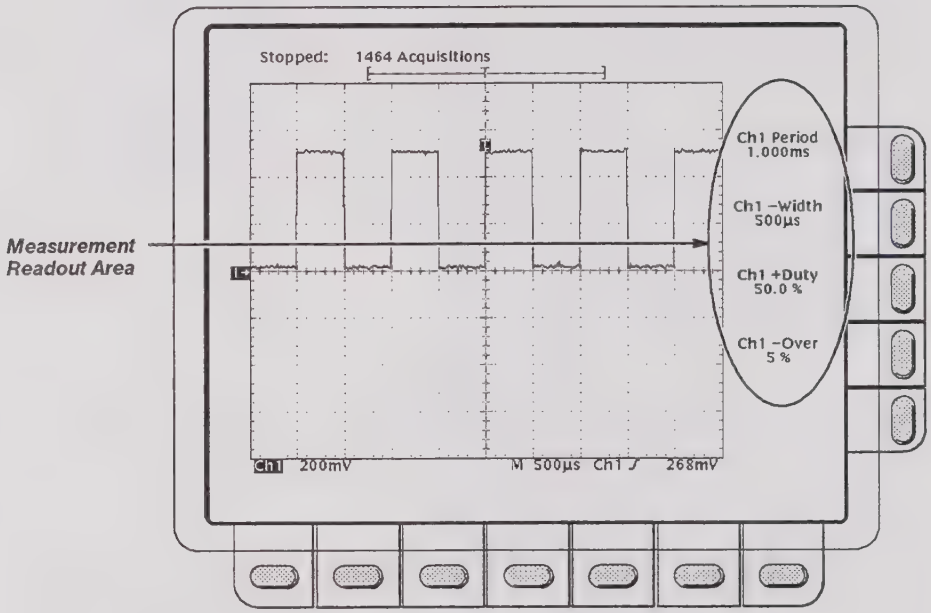


Figure 3-33: Measurement Readouts

Operation

To use the automatic measurements you first need to obtain a stable display of the waveform to be measured. Pressing the **AUTOSET** button may help.

Once you have a stable display, press the **MEASURE** button to bring up the Measure menu (Figure 3-34).

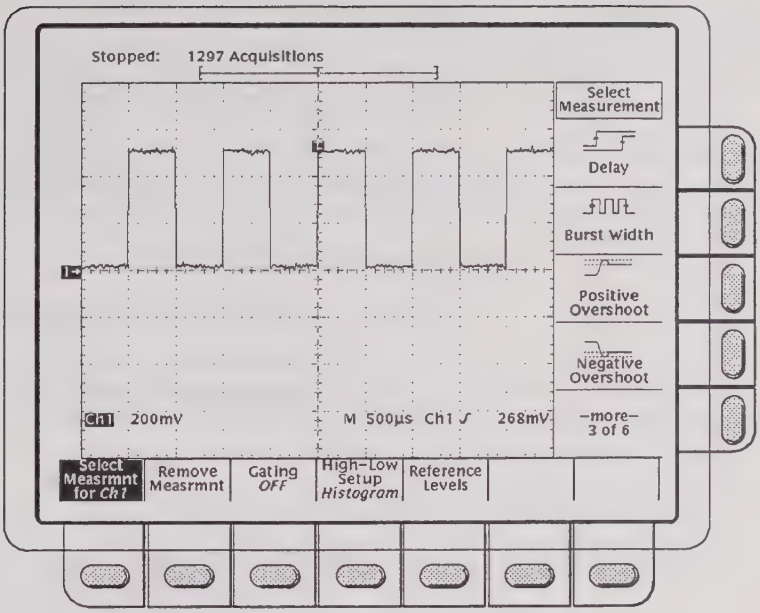


Figure 3-34: Measure Menu

Selecting a Measurement

You can choose up to four measurements at any one time. Measurements are made on the selected waveform. The measurement display tells you the channel the measurement is being made on.

☐ **Step 1:** Press the main menu **Select Measrmnt** button.

☐ **Step 2:** Select a measurement from the side menu.

The following are hints on making automatic measurements:

- You can only take a maximum of four measurements at a time. To add a fifth, you must remove one or more of the existing measurements.
- To vary the source for measurements, simply select the other channel and then choose the measurements you want.
- Be careful when taking automatic measurements on noisy signals. You might measure the frequency of the noise and not the desired waveform.

  Your digitizing oscilloscope helps identify such situations by displaying a *low signal amplitude* or *low resolution* warning message.

  You can minimize most noise problems by changing the vertical scale to increase the waveform height. You can also change the acquisition mode. You might use Hi Res mode, which averages out high frequency noise, rather than the noise sensitive Peak Detect mode.

Removing Measurements

The **Remove Measrmnt** selection provides explicit choices for removing measurements from the display according to their readout position.

Measurement 1 is the top readout. Measurement 2 is below it, and so forth. The measurement stay in their positions even when you remove measurements above them.

To remove measurements:

- ☐ **Step 1:** Select the **Remove Measrmnt** main menu item.
- ☐ **Step 2:** Select the measurement to remove from the side menu. If you want to remove all the measurements at one time, press **All Measurements**.

Gated Measurements

The gating feature lets you limit measurements to a specified portion of the waveform. When gating is **Off**, the oscilloscope makes measurements over the entire waveform record.

When gating is activated, vertical cursors are displayed and you use these to define the section of the waveform you want the oscilloscope to measure. This is called the *gated region*.

- ☐ **Step 1:** Select **Gating** from the main menu.
- ☐ **Step 2:** Press the side menu button next to **Gate with V Bar Cursors** (see Figure 3-35).

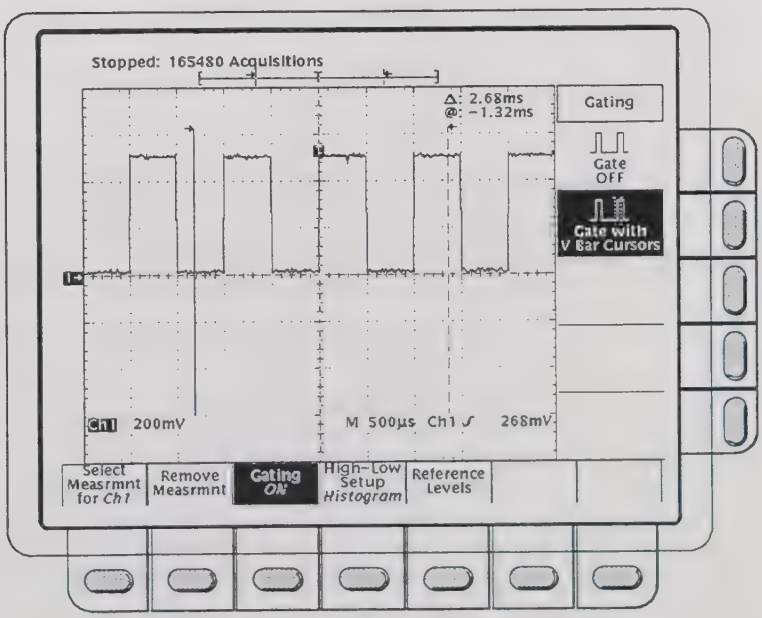


Figure 3-35: Measure Menu—Gating

☐ **Step 3:** Using the general purpose knob, move the selected (the active) cursor. Use the **TOGGLE** button to change which cursor is active. A solid line indicates the active cursor and a dashed line shows the inactive cursor.

You can change the cursor speed by pressing **SHIFT** before turning the general purpose knob. When the light next to the **SHIFT** button is on and the display says **Coarse Knobs** in the upper right corner, the cursors move significantly faster.

NOTE

Cursors are displayed relative to the selected waveform. If you are making a measurement using two waveforms, this can be a source of confusion. If you turn off horizontal locking and adjust the horizontal position of one waveform independent of the other, the cursors appear at the requested position with respect to the selected waveform. Gated measurements remain accurate, but the displayed position of the cursors change when you change the selected waveform.

High-Low Setup

The **High-Low Setup** item provides two choices for how the oscilloscope determines the High and Low levels of waveforms. These are: *histogram* and *min/max*.

- Histogram sets the values statistically. It selects the most common value either above or below the mid point (depending on whether it is defining the high or low reference level). That method is useful when examining pulses.
- Min/max uses the highest and lowest values of the waveform record.

To use the high-low setup:

☐ **Step 1:** Select the **High-Low Setup** main menu item (Figure 3-36).

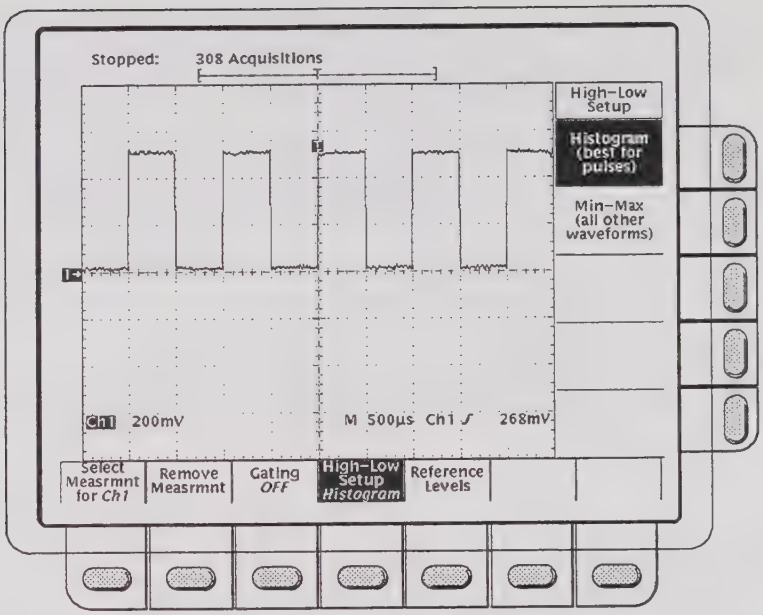


Figure 3-36: Measure Menu—High-Low Setup

☐ **Step 2:** Select either **Histogram** or **Min-Max** from the High-Low side menu. If you select **Min-Max**, you may also want to check and/or revise values using the Reference Levels main menu.

Reference Levels

You can set the measurement system's vertical reference levels with the **Reference Levels** main menu item. Once you define these levels, the digitizing oscilloscope will use them for all measurements requiring those levels.

☐ **Step 1:** Press **Reference Levels** on the main menu (see Figure 3-37).

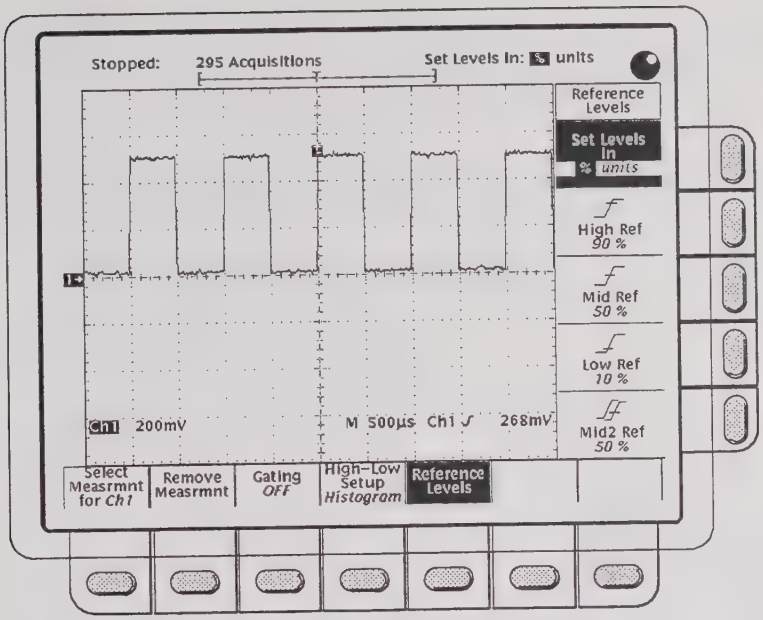


Figure 3-37: Measure Menu—Reference Levels

☐ **Step 2:** Press **Set Levels** to choose whether the References are set in % relative to High (100%) and Low (0%), or set explicitly in the units of the selected waveform (typically volts). Use the general purpose knob to enter the values.

- **%** is the default selection. It's useful for many general purpose applications.
- **Units** is helpful for setting precise values. For example, if you're trying to measure specifications on an RS-232-C circuit, you can set the levels precisely to RS-232-C specification voltage values by defining the high and low references in units.

☐ **Step 3:** Select which reference level you want to set. There are four reference levels you can define:

High Ref—Sets the high reference level. The default is 90%.

Mid Ref—Sets the middle reference level. The default is 50%.

Low Ref—Sets the low reference level. The default is 10%.

Mid2 Ref—Sets the middle reference level used on the second waveform specified in the Delay Measurements. The default is 50%.

Delay Measurement

The delay measurement lets you measure from the selected waveform to another waveform. You access the Delay Measurement menu through the Measure main menu:

☐ **Step 1:** Press the main menu **Select Measrmnt** button.

☐ **Step 2:** Select **Delay** from the side menu. This brings up the Measure Delay main menu (Figure 3-38).

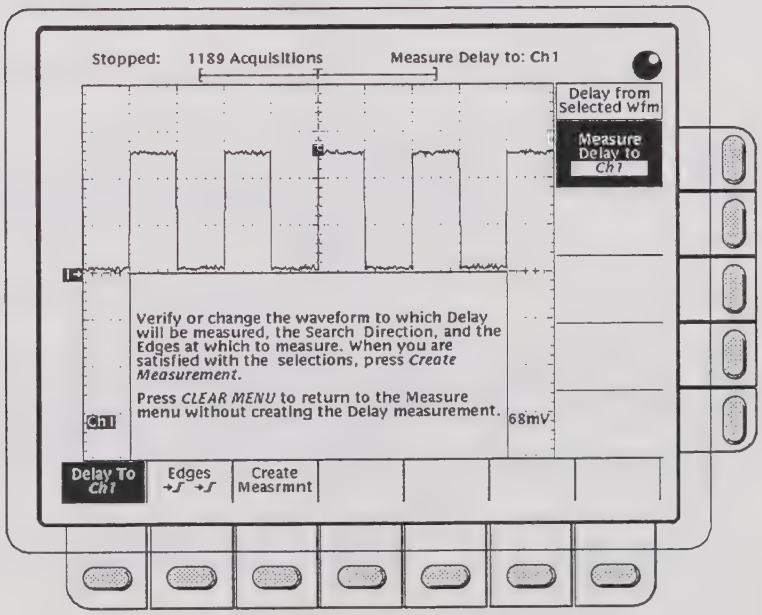

Stopped: 1189 Acquisitions
Measure Delay to: Ch1
Delay from Selected Wfm
Measure Delay to Ch1
Verify or change the waveform to which Delay will be measured, the Search Direction, and the Edges at which to measure. When you are satisfied with the selections, press Create Measurement.
Press CLEAR MENU to return to the Measure menu without creating the Delay measurement.
Ch1
68mV
Delay To Ch1
Edges
Create Measrmnt

Figure 3-38: Measure Delay Menu—Delay To

Delay to—To select the waveform you want to measure *to*, use the the main menu item **Delay to.** The waveform you are measuring *from* is the selected waveform.

☐ **Step 3:** On the Measure Delay menu press **Delay To**. It provides a side menu with one item: **Measure Delay to**.

☐ **Step 4:** Press the side menu button repeatedly or turn the general purpose knob to choose the delay *to* waveform. The choices are: **Ch1**, **Ch2**, **Ch3, Ch4**, **Math1**, **Math2**, **Math3**, **Ref1**, **Ref2**, **Ref3**, and **Ref4**.

Delay Edges – The main menu item **Edges** lets you specify which edges you want the delayed measurement to be made between.

☐ **Step 5:** On the Measure Delay menu, press the main menu button with the label **Edges**. A side menu of delay edges and directions will appear (Figure 3-39).

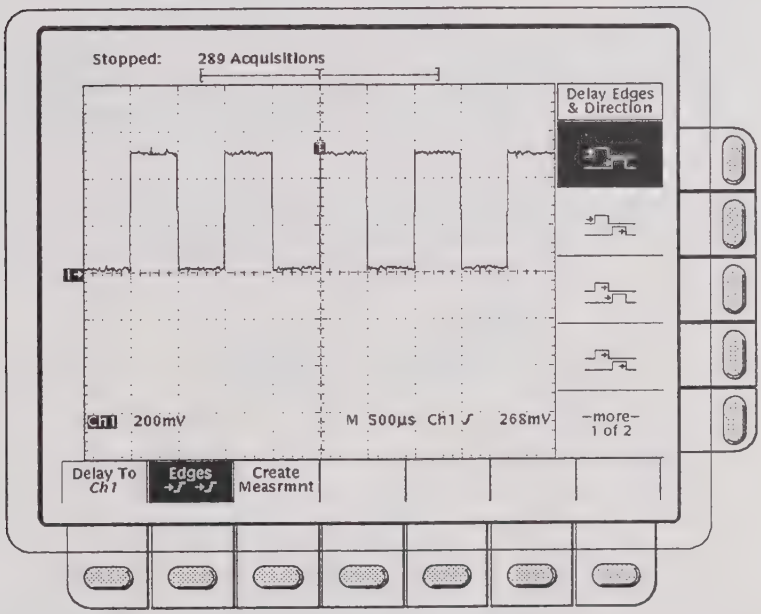


Figure 3-39: Measure Delay Menu – Edges

☐ **Step 6:** Choose from one of the combinations displayed on the side menu.

The upper waveform on each icon represents the *from* waveform and the lower one represents the *to* waveform.

The direction arrows on the choices let you specify a forward search on both waveforms, or a forward search on the *from* waveform and a backwards on the *to* waveform. The latter choice is useful for isolating a specific pair of edges out of a stream.

Creating the Delay Measurement – Once you have specified the waveforms you are measuring between and which edges to use, you need to notify the digitizing oscilloscope to proceed with the measurement.

☐ **Step 7:** Press the main menu **Create Measrmnt** button.

☐ **Step 8:** On the side menu press **OK Create Measurement**. The oscilloscope will then make the specified delay measurement and return you to the Measure menu.

To exit the Measure Delay menu without creating a delay measurement, press the **CLEAR MENU** button, which returns you to the Measure menu.

For More Information

See *Measurements*, on page 2-25.

See *Appendix D: Algorithms*, on page A-75.

Probe Accessories

The probe you use and how you connect it to a signal source affect the oscilloscope's acquisition of the waveform record. Two important factors are:

- ground lead inductance (introduced by the probe), and
- the physical layout of your circuit and component devices.

The Importance of Ground Lead Inductance

For an amplitude measurement to be meaningful, you must give the measurement some point of reference. Your probe offers you the capability for referencing the voltage at its tip to ground. To make your measurement as accurate as possible, the probe's ground lead should be connected to the ground reference.

However, when you touch your probe tip to a circuit element, you are introducing new resistance, capacitance, and inductance into the circuit (Figure 3-40).

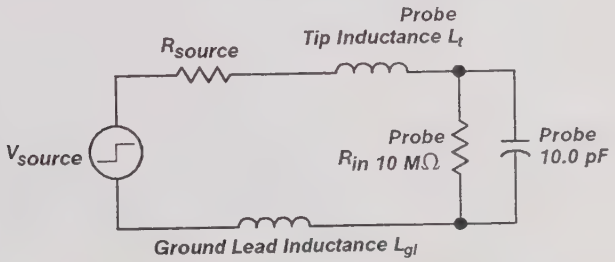


Figure 3-40: A Probe Adds Resistance, Capacitance, and Inductance

For most circuits, the high input resistance of a passive probe has a negligible effect on the signal. The series inductances represented by the probe tip and ground lead, however, can result in a parasitic resonant circuit that may "ring" within the bandwidth of the oscilloscope. Figure 3-41 shows the effect of the same signal through the same probe with different ground leads.

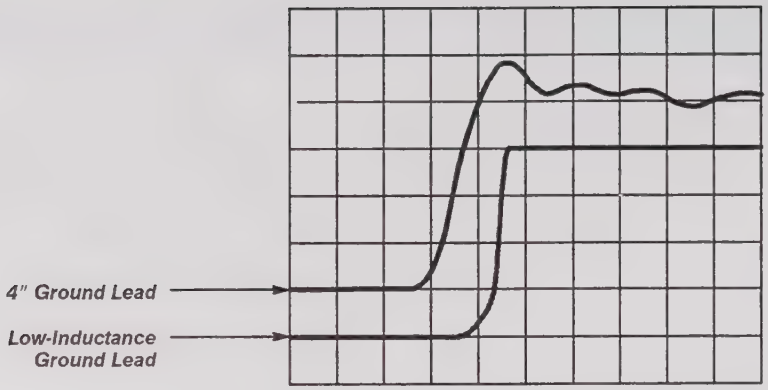


Figure 3-41: Signal Variation Introduced by Probe Ground Lead (1 ns/division)

Ringing and rise time degradation may be hidden if the frequency of the induced ringing is beyond the bandwidth of the oscilloscope. If you know the self-inductance (*L*) and capacitance (*C*) of your probe and ground lead, you can calculate the approximate resonant frequency (f_0) at which that parasitic circuit will resonate:

$$f_0 = \frac{1}{2\pi \times \sqrt{LC}}$$

Reducing the ground lead inductance will raise the resonant frequency. Ideally, the inductance is low enough that the resulting frequency is above the frequency at which you want to take measurements. For that purpose, the probes include several accessories to help reduce ground lead inductance.

Probe Accessories Overview

The following descriptions explain how to use many of the accessories that came with your probe as well as optional ones you can order. Figure 3-42 shows both standard and optional probe accessories and how they attach to your probe.

These accessories either reduce ground lead inductance or make it physically easier to probe different kinds of circuits.

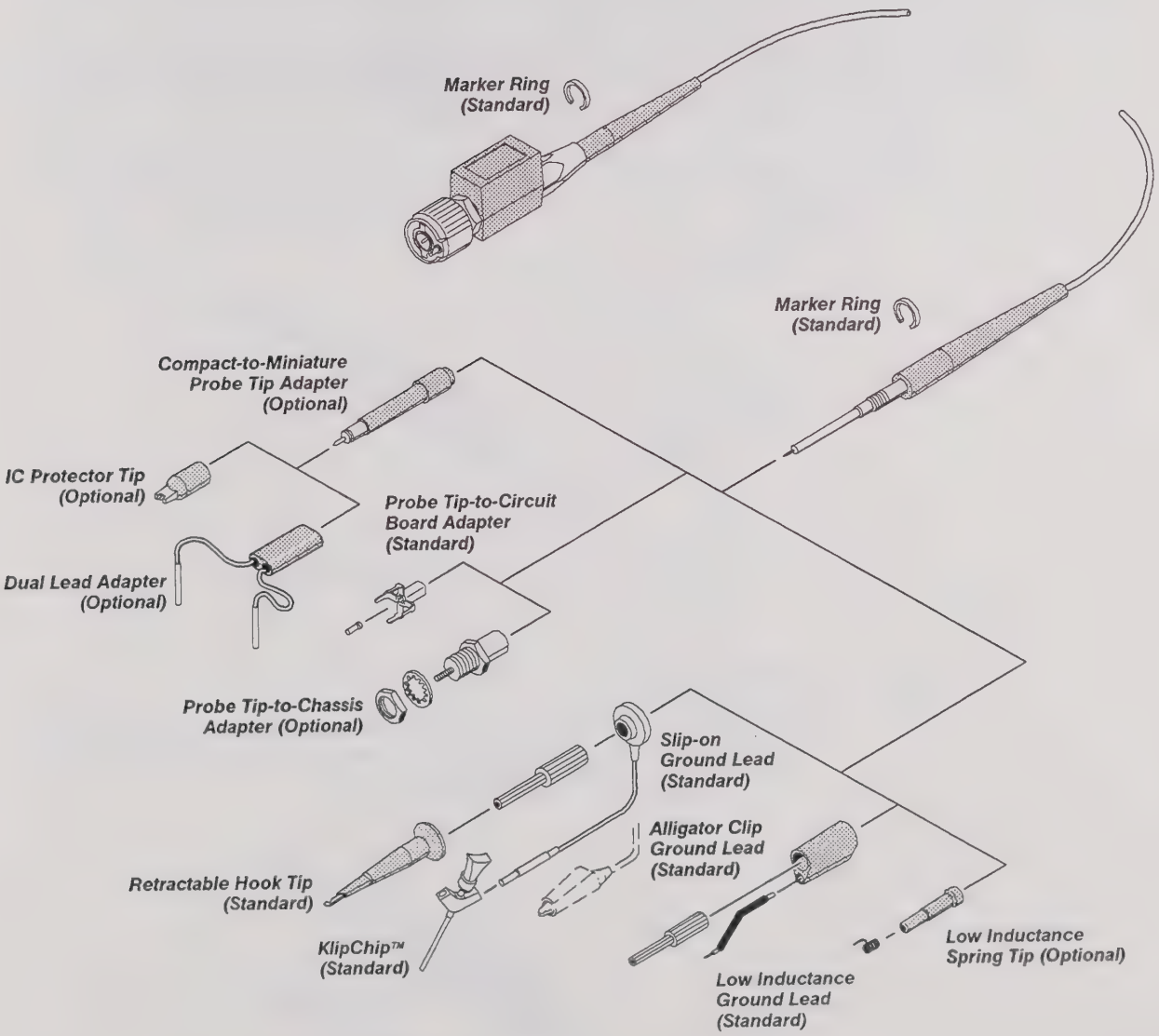

Marker Ring (Standard)
Marker Ring (Standard)
Compact-to-Miniature Probe Tip Adapter (Optional)
IC Protector Tip (Optional)
Probe Tip-to-Circuit Board Adapter (Standard)
Dual Lead Adapter (Optional)
Probe Tip-to-Chassis Adapter (Optional)
Slip-on Ground Lead (Standard)
Alligator Clip Ground Lead (Standard)
Retractable Hook Tip (Standard)
KlipChip™ (Standard)
Low Inductance Spring Tip (Optional)
Low Inductance Ground Lead (Standard)

Figure 3-42: Probe Accessories

Standard Probe Accessories

Standard probe accessories include the following:

Retractable Hook Tip

The retractable hook tip attaches to your signal test point for hands-free operation of the probe. The hook tip attaches to components having leads, such as resistors, capacitors, and discrete semiconductors. You can also grip stripped wire, jumpers, busses, and test pins with the retractable hook.

For maximum flexibility with the hook tip, use one of the six-inch ground leads. For precise measurements at high frequency, however, long ground leads may have too much inductance. In these cases you can use one of the low-inductance probe tip configurations instead.

To remove the hook tip, simply pull it off the probe. Reinstall it by pushing it firmly onto the ribbed ferrule of the probe tip (see Figures 3-42 and 3-43).

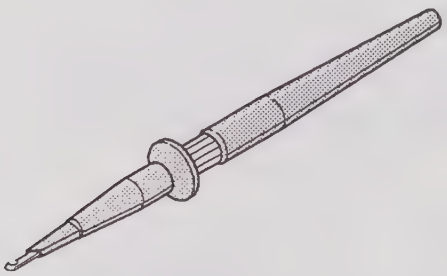


Figure 3-43: Retractable Hook Tip

Marker Rings

The marker rings help you keep track of individual probes and signal sources when you have a complicated test setup. Use the marker rings whenever you want to identify a particular probe (Figure 3-44).

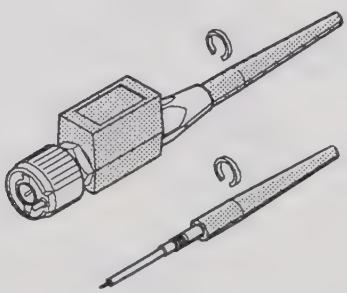


Figure 3-44: Marker Rings

Long Ground Leads

Use long ground leads when a long reach is important and high-frequency information is not. Long ground leads are ideal for quick troubleshooting when you are looking for the presence or absence of a signal and are not concerned with the precision of the measurement.

Because of the high inductance associated with long ground leads, you should not use them for precise measurements above approximately 30 MHz (or for pulses with rise times less than about 11 ns).

You can choose between a ground lead terminated with an alligator clip and a lead terminated with a square-pin receptacle (see Figure 3-45).

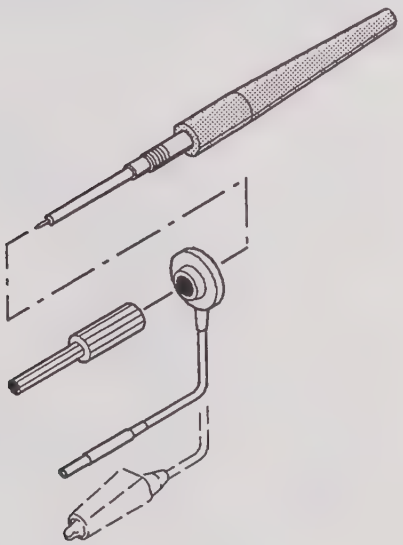


Figure 3-45: Long Ground Leads

Low-Inductance Ground Lead

Low-inductance ground leads substantially reduce ground lead inductance. Compared to a typical six-inch ground lead with an inductance of approximately 140 nH, the low-inductance tip assembly has an inductance of approximately 32 nH. That means that your measurements will be relatively free of probe-related high-frequency degradation up to approximately 250 MHz.

The low-inductance tip has a partially insulated flexible ground pin that allows you to ground the probe and still have a limited amount of reach with the probe tip. Because the ground lead simply contacts the ground reference (instead of clipping onto it) you can move the probe around your device under test with ease (see Figure 3-46). The assembly is well-suited to densely populated circuit boards and multi-pin connectors.

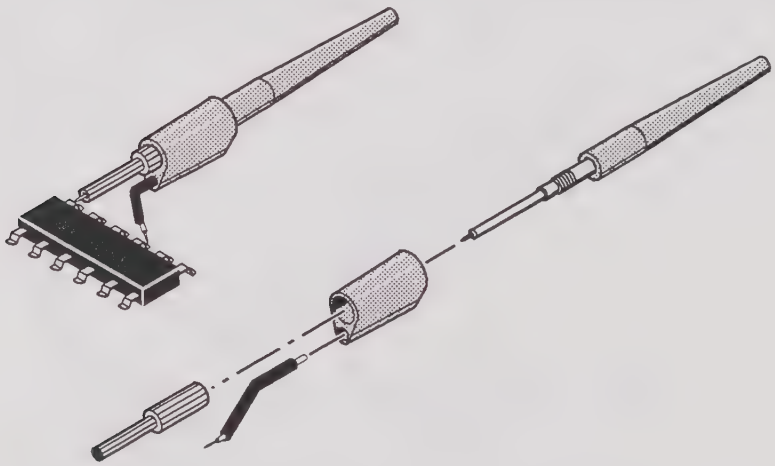


Figure 3-46: Low-Inductance Ground Lead

Probe-Tip-to-Circuit Board Adapters

The probe-tip-to-circuit board adapters let you design minimum inductance test points into your next circuit board. That adapter provides maximum performance for the probe, because it virtually eliminates the probe's ground inductance effects.

Instructions for installing the probe tip-to-circuit board adapters are packaged with the adapters. For the best performance and ease of testing, Tektronix strongly recommends that you incorporate the probe tip-to-circuit board adapters (or the probe tip-to-chassis adapters described below) into your next design.

To use your probe with these adapters, unscrew and remove the ribbed ferrule. Use the probe tip directly with the adapter (see Figure 3-47).

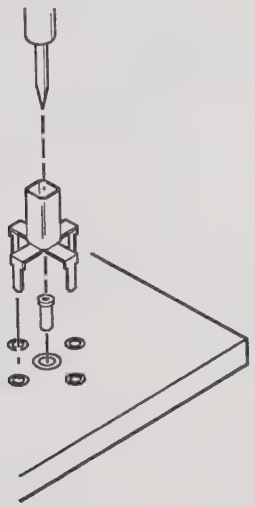


Figure 3-47: Probe-Tip-to-Circuit Board Adapter

SMT KlipChip™

The SMT KlipChip provides hands-free attachment to a physically small signal or ground source (Figure 3-48). The low profile of the KlipChip allows you to grasp surface-mounted devices that the full-size retractable hook tip can't grip.

You can use the KlipChip as a ground attachment, as a signal attachment, or to attach both to a ground and a signal.

- For a ground attachment, use the long ground lead (described on page 3-71) terminated with a pin receptacle and connect the termination to the pin in one of the KlipChip shoulders.
- For a signal attachment, use a single-lead adapter (similar to the dual-lead adapter described on page 3-78) and connect the termination to the pin in one of the KlipChip shoulders.
- For both ground and signal attachment, combine two KlipChips with a dual-lead adapter, or use a single-lead adapter along with a long ground lead.

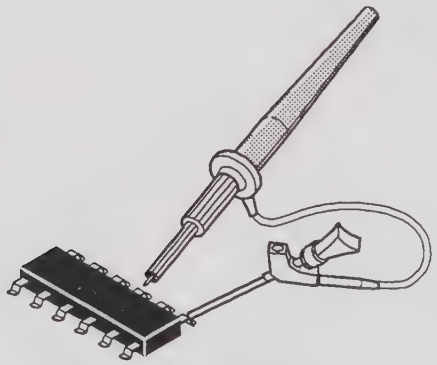


Figure 3-48: SMT KlipChip™ As Ground Attachment

Optional Probe Accessories

Optional probe accessories include the following:

Low-Inductance Spring Tips

The low-inductance spring tips can be used whenever you are measuring devices with fixed spacings. The spring-tip is ideal for repetitive production use. Select different length springs to match device spacings on a variety of components. Because the spring-tip ground lead simply contacts the ground reference (instead of clipping onto it) you can move the probe around your device-under-test with ease.

To attach the low-inductance spring-tip assembly, remove the ribbed ferrule (and long ground lead) if installed. Slip the smooth plastic ferrule onto the probe tip and push it firmly against the molded portion of the cable. Select a spring tip and push it onto the metal barrel of the probe tip (Figure 3-49).

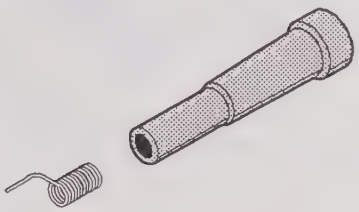


Figure 3-49: Low-Inductance Spring-Tips

Probe-Tip-to-Chassis Adapter

The probe-tip-to-chassis adapter makes your test point accessible without removing instrument covers or panels. It provides an easy-access, low-inductance test point anywhere on your circuit (Figure 3-50). The probe-tip-to-chassis adapter has the same low inductance properties as the probe-tip-to-circuit board adapter described previously.

To use your probe with these adapters, unscrew and remove the ribbed ferrule.

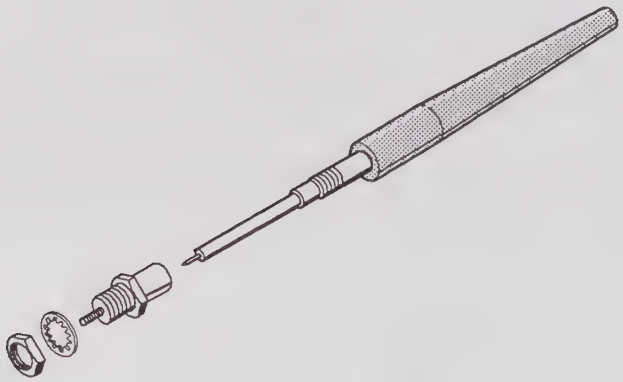


Figure 3-50: Probe-Tip-to-Chassis Adapter

Compact-to-Miniature Probe Tip Adapter

The compact-to-miniature probe tip adapter allows you to use accessories that are designed to accept a larger probe tip (Figure 3-51). These accessories include the IC protector tip, single- and dual-lead adapters, and others.

To install the adapter, unscrew and remove the ribbed ferrule and screw the adapter on in its place. (The IC protector tip discussed below is installed on the adapter tip when shipped. Remove the protector tip by pulling it off before using the adapter with other accessories.)

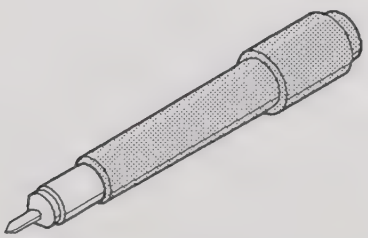


Figure 3-51: Compact-to-Miniature Probe Tip Adapter

IC Protector Tip

The IC protector tip simplifies probing inline IC packages (Figure 3-52). The shape of the IC protector guides the probe tip to the IC pin and prevents accidental shorting of pins by the probe tip. It is used with the compact-to-miniature probe tip adapter. When using that tip, the spacing (pitch) between leads should be greater than or equal to 0.100 inches (100 mils).

Because the IC protector tip prevents you from using the low-inductance tips, you will have to use one of the longer ground leads. For that reason you should take into account ground lead inductance effects on measurements at frequencies greater than about 30 MHz.

To attach the IC protector tip, push it firmly onto the end of the metal barrel of the compact-to-miniature probe tip adapter.

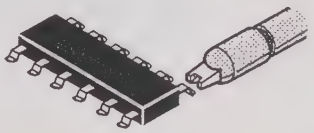


Figure 3-52: IC Protector Tip

Dual-Lead Adapter

The dual-lead adapter makes an easy connection to 0.025 diameter connector pins (Figure 3-53). One lead connects to a ground reference pin, and the other to the signal pin. The adapter prevents burring and pin damage that can result when a retractable hook tip is used on soft pins. A single-lead adapter is also available. These adapters can also be used with the SMT KlipChip to provide access to very small signal and ground test points.

Although the dual-lead adapter is an improvement over the long ground leads in terms of added inductance, measurements at frequencies greater than 30 MHz may require using one of the low-inductance ground leads. Because of the length of the signal lead, the dual-lead configuration is also more susceptible to signal crosstalk than other tip configurations.

To use the dual-lead adapter you must first install the optional compact-to-miniature probe tip adapter (or a KlipChip, see Figure 3-48). Remove the ribbed ferrule if it is installed. Screw the compact-to-miniature adapter onto the probe tip. Then insert the miniature probe tip into the dual-lead adapter.

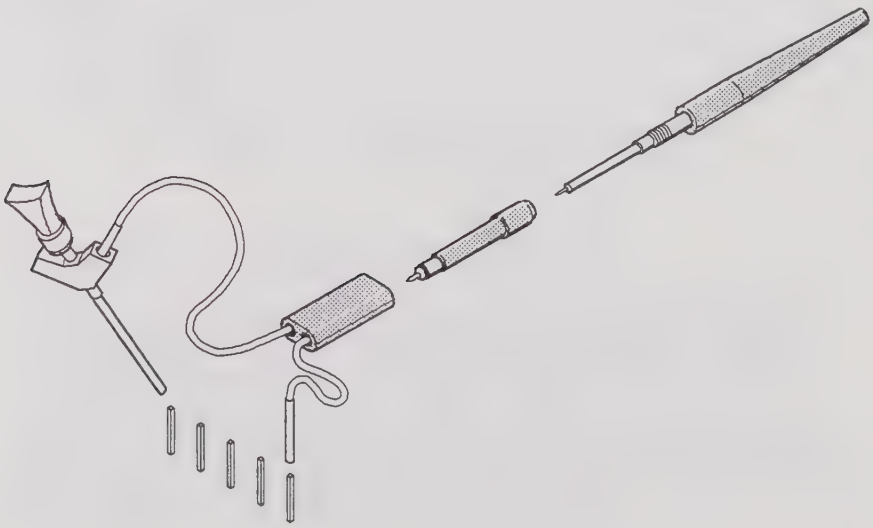


Figure 3-53: Dual-Lead Adapter

Probe Compensation

Passive probes require compensation to ensure maximum distortion-free input to the digitizing oscilloscope and to avoid high frequency amplitude errors (see Figure 3-54).

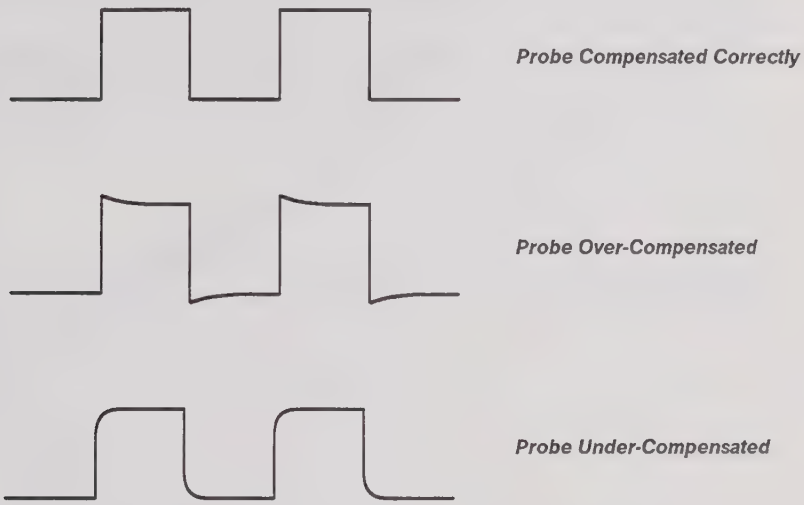


Figure 3-54: How Probe Compensation Affects Signals

Operation

To compensate your probe:

☐ **Step 1:** Connect the probe to the probe compensation signal on the front panel.

☐ **Step 2:** Press the **AUTOSET** button.

NOTE

When you connect an active probe to the oscilloscope (such as the P6205), the input impedance of the oscilloscope automatically becomes 50 Ω. If you then connect a passive probe (like the P6138) you need to set the input impedance back to 1 MΩ. Step 5 explains how to change the input impedance.

You now need to limit the bandwidth.

☐ **Step 3:** Press the **VERTICAL MENU** button.

- ☐ **Step 4:** Select **Bandwidth** from the main menu and **20 MHz** from the resulting side menu.
- ☐ **Step 5:** If you need to change the input impedance, select **Coupling** from the main menu. Then toggle the side menu selection Ω to get the correct impedance.
- ☐ **Step 6:** Press the **ACQ MENU** (**SHIFT** and then **RUN/STOP**) button.
- ☐ **Step 7:** Select **Mode** from the main menu and **Hi Res** from the resulting side menu.
- ☐ **Step 8:** Adjust the trimmer in the probe until you see a perfectly flat top square wave on the display. Figure 3-55 shows where the adjustment trimmer is located.

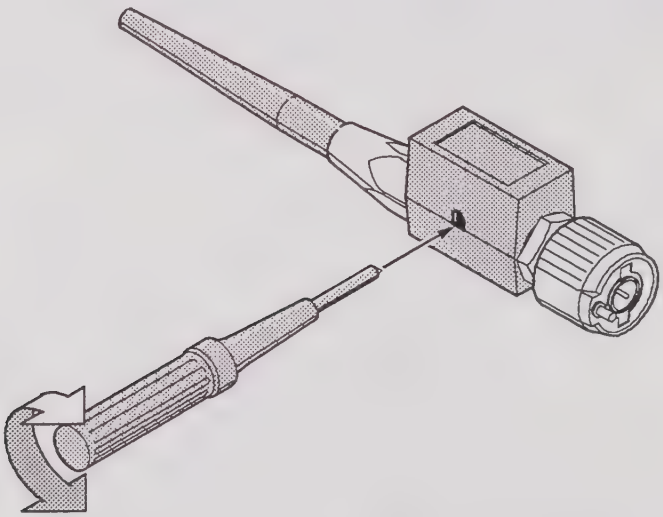


Figure 3-55: P6138 Probe Trimmer Adjustment

For More Information

See *Probe Accessories*, on page 3-67.

See *Probe Selection*, on page 3-81.

Probe Selection

The probes included with your digitizing oscilloscope are useful for a wide variety of tasks. However, for special measurement situations you sometimes need different probes. This section helps you select the right probe for the job.

Once you have decided the type of probe you need, use Table 3-5 to determine the specific probe compatible with your TDS 400 Digitizing Oscilloscope.

Or use Table 3-6 if you want to select the probe by application.

There are five types of probes: passive, active, current, optical, and time-to-voltage probes.

Passive Voltage Probes

Passive voltage probes measure voltage. They employ passive circuit components such as resistors, capacitors, and inductors. Three common classes of passive voltage probes are:

- *General purpose (high input resistance)*
- *Low impedance (Zo)*
- *High voltage*

General Purpose (High Input Resistance) Probes

High input resistance probes are considered "typical" oscilloscope probes. The P6138 probes included with the digitizing oscilloscope are passive probes. The high input resistance of passive probes (typically 10 MΩ) provides negligible DC loading. That makes them a good choice for accurate DC amplitude measurements.

On the negative side, their 9 pF to 12 pF (over 60 pF for 1X) capacitive loading can distort timing and phase measurements. Use high input resistance passive probes for measurements involving:

- device characterization (above 15 V, thermal drift applications)
- maximum amplitude sensitivity using 1X high impedance
- large voltage range (between 15 and 500 V)
- qualitative or go/no-go measurements

CAUTION

Do not use the P6062B probe with a TDS 400 Series Digitizing Oscilloscope. Repeated use of that probe may damage the input connector on the oscilloscope.

Low Impedance (Zo) Probes

Low impedance probes measure frequency more accurately than general purpose probes, but they make less accurate amplitude measurements. They offer a higher bandwidth to cost ratio.

These probes must be terminated in a 50 Ω scope input. Input capacitance is much lower than high Z passive probes, typically 1 pF, but input resistance is also lower (500 to 5000 Ω typically). Although that DC loading degrades amplitude accuracy, the lower input capacitance reduces high frequency loading to the circuit under test. That makes Zo probes ideal for timing and phase measurements.

Zo probes are useful for measurements up to 40 V.

High Voltage Probes

High voltage probes have attenuation factors in the 100X to 1000X range. The considerations that apply to other passive probes apply equally well to high voltage probes with a few exceptions. Since the voltage range on high voltage probes varies from 1 kV to 20 kV (DC + peak AC), the probe head design is mechanically much larger than for a passive probe. High voltage probes have the added advantage of lower input capacitance.

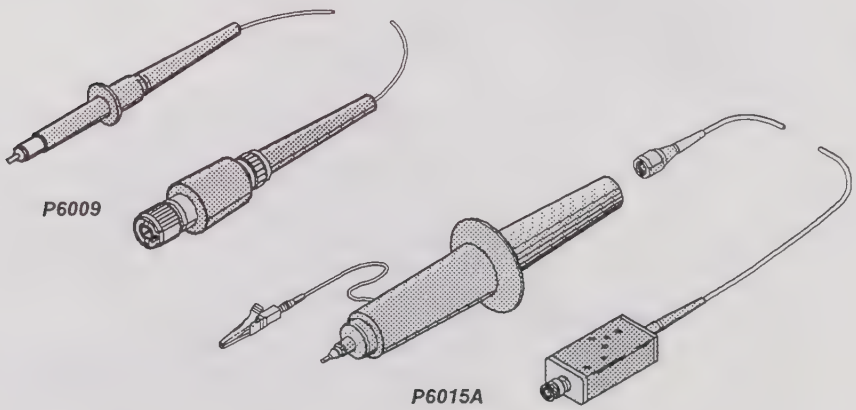


Figure 3-56: The P6009 and P6015A High Voltage Probes

Active Voltage Probes

Active voltage probes, sometimes called "FET" probes, use active circuit elements such as transistors. Three common classes of active probes are:

- *High speed active*
- *Differential active*
- *Fixtured active*

Active voltage measuring probes use active circuit elements in the probe design to process signals from the circuit under test. All active probes require a source of power for their operation. Power is obtained either from an external power supply or from the oscilloscope itself.

Active probes offer low input capacitance (1 to 2 pF typical) while maintaining the higher input resistance of passive probes (10 kΩ to 10 MΩ). Like Zo probes, active probes are useful for making accurate timing and phase measurements. However, they do not degrade the amplitude accuracy. Active probes typically have a dynamic range of ±10 to ±15 V.

NOTE

When you connect an active probe to the oscilloscope (such as the P6205), the input impedance of the oscilloscope automatically becomes 50 Ω. If you then connect a passive probe (like the P6138) you need to set the input impedance back to 1 MΩ. Vertical Control *on page 3-107 explains how to change the input impedance.*

Differential Probes

Differential probes determine the voltage drop between two points in a circuit under test. Differential probes let you simultaneously measure two points and to display the difference between the two voltages.

An active differential amplifier in the probe head results in high common-mode signal rejection at higher frequencies. That amplifier minimizes the measurement errors caused by differences in probes, cable lengths, and input attenuators.

The common mode rejection ratio is a measure of how effectively the probe cancels signals that are common to both inputs. The common mode range indicates the maximum amplitude the common signal can reach before the probe circuitry is saturated.

Active differential probes are stand alone products designed to be used with 50 Ω inputs. The same characteristics that apply to active probes apply to active differential probes.

Fixtured Active Probes

In some small-geometry or dense circuitry applications, such as surface mounted devices (SMD), a hand-held probe is too big to be practical. You can instead use fixtured (or probe card mounted) active probes (or buffered amplifiers) to precisely connect your instrument to your device-under-test. These probes have the same electrical characteristics as high speed, active probes but use a smaller mechanical design.

Current Probes

Current probes enable you to directly observe and measure current waveforms, which can be very different from voltage signals. Tektronix current probes are unique in that they can measure from DC to 1 GHz.

Two types of current probes are available: one that measures AC current only, and AC/DC probes that utilize the Hall effect to accurately measure the AC and DC components of a signal. AC-only current probes use a transformer to convert AC current flux into a voltage signal to the oscilloscope and have a frequency response from a few hundred Hertz up to 1 GHz. AC/DC current probes include Hall effect semiconductor devices and provide frequency response from DC to 50 MHz.

Use a current probe by clipping its jaws around the wire carrying the current that you want to measure. (That is not like an ammeter, which you must connect in series with the circuit.) Because current probes are non-invasive, with loading typically in the mΩ to low Ω range, they are especially useful where low loading of the circuit is important. Current probes can also make differential measurements by measuring the results of two opposing currents in two conductors in the jaws of the probe.

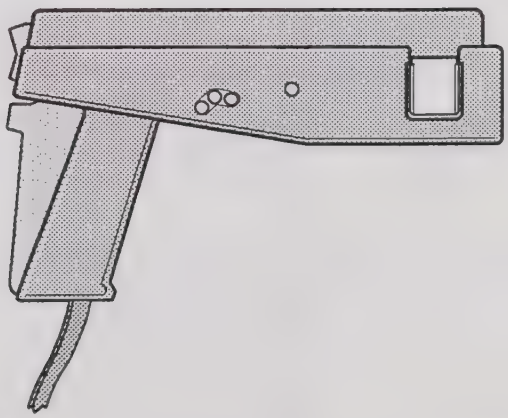


Figure 3-57: A6303 Current Probe Used in the AM 503S Opt. 03

Optical Probes

Optical probes let you blend the functions of an optical power meter with the high-speed analog waveform analysis capability of an oscilloscope. You have the capability of acquiring, displaying, and analyzing optical and electrical signals simultaneously.

Applications include measuring the transient optical properties of lasers, LEDs, electro-optic modulators, and flashlamps. You can also use these probes in the development, manufacturing, and maintenance of fiber optic control networks, local area networks (LANs), fiber-based systems based on the FDDI and SONET standard, optical disk devices, and high-speed fiber optic communications systems.

NOTE

Tektronix optical probes have 1X attenuation, but the display shows measurement values for 10X attenuation. Also, the measurements are in volts instead of watts. To convert the measurements to the proper values use the equation on the side of the probe. For example, the message on the side of the P6701A states that there is 1 V/mW. Table 3-4 shows how you would take a display measurement and calculate the correct value if you used that probe.

Also you need to set the input impedance of the digitizing oscilloscope to 50 Ω.

Table 3-4: P6701A Optical Probe Measurement Conversion

Displayed Measurement	Correction for 1X Attenuation	Conversion to Watts from Volts
1 V	0.1 V	0.1 mW
0.1 V	0.01 V	0.01 mW

Time-to-Voltage Converter

The instantaneous time-interval to voltage converter (TVC) continuously converts consecutive timing measurements to a time-interval versus time waveform.

Timing variations typically appear as left-to-right motion, or jitter, on an oscilloscope. Time base or trigger holdoff adjustments may improve display stability, but they do not show timing dynamics. The TVC untangles the often confusing waveforms and delivers a coherent real-time view.

The TVC adds three measurement functions to your oscilloscope's voltage versus time capability: time delay versus time, pulse-width versus time, and period versus time.

The TVC continuously measures the timing parameter and instantaneously generates a voltage proportional to the measurement. Since the TVC generates voltages proportional to time-intervals, you can set your scope to trigger on timing violations such as a time-delay that exceeds a threshold or an incorrectly narrow pulse or glitch.

Probes by Type

Table 3-5 lists TDS 400 compatible probes classified by type.

Table 3-5: TDS 400 Compatible Probes

Probe Type	Tektronix Model	Description
Passive, high impedance voltage	P6138 (std.) P6101A	10X, 350 MHz 1X, 15 MHz
Passive, low impedance Zo (low capacitance)	P6156 P6562	10X, 3.5 GHz, for 50 Ω inputs (1X, 20X, 100X optional) SMT, 350 MHz
Passive, high voltage	P6009 P6015A	100X,1.5 kV, DC + peak AC 1000X, 20 kV, DC + peak AC
Active, high speed voltage	P6205	DC to 750 MHz FET
Active, differential voltage	P6046	1X/10X, DC to 100 MHz
Active, fixtured voltage	A6501 P6501 Opt. 02	Buffer Amplifier, 1 GHz, 1 MΩ, 10X Microprobe with TekProbe Power Cable, 750 MHz, 1 MΩ, 10X
Current	AM 503S AM 503S Opt. 03 P6021 P6022 CT-1/CT-2 CT-4	AC/DC. Uses A6302 Current Probe. AC/DC. Uses A6303 Current Probe. AC. 120 Hz to 60 MHz. AC. 935 kHz to 120 MHz. Designed for permanent or semi-permanent in-circuit installation CT-1: 25 kHz to 1 GHz, 50 Ω input CT-2: 1.2 kHz to 200 MHz, 50 Ω input Current Transformer for use with AM 503S and P6021. Peak pulse 1 kA, 0.5Hz to 20 MHz with AM 503S
Optical (Opto-Electronic Converters)	P6701A P6703A P6711 P6713	500 to 950 nm, DC to 850 MHz, 1 V/mW 1100 to 1700 nm, DC to 1 GHz, 1 V/mW 500 to 950 nm, DC to 250 MHz, 5 V/mW 1100 to 1700 nm, DC to 300 MHz, 5 V/mW
Time-to-Voltage Converter	TVC 501	Time delay, pulse width and period measurements

Probes by Application

Another way to classify probes is by application. Different applications demand different probes. Use Table 3-6 to select a probe for your application.

Table 3-6: Probes by Application

Probe Type	Telecommunications & High-Speed Logic	Industrial Electronics	Consumer/ Computer Electronics	High Energy Pulsed Power	Certification, Regulatory, & Compliance Testing
Passive, high-impedance voltage	P6138[1] P6101A[1]	P6138[1,2] P6101A[1,2]	P6138[1,2,3] P6101A[1]	P6138[1,2,3] P6101A[1,2]	P6138[1,2,3] P6101A[1,2]
Active, high-speed digital voltage	P6205[2,3] P6204[2,3]	P6205[2,3]	P6205[2,3] P6204 w/1103 power supply[2,3]	P6205[2,3]	P6205[2,3]
Low impedance Zo (low capacitance)	P6156[1,2,3]		P6156[1,2,3]		
Passive, high voltage	P6009[1,2]	P6009[1,2,3] P6015A[1,2,3]	P6009[1,2]	P6009[1,2,3] P6015A[1,2,3]	P6009[1,2,3] P6015A[1,2,3]
Active, differential voltage	P6046[2,3]	P6046[2,3]	P6046[2,3]		
Current	AM 503S[2,3] P6021[1,2]	AM 503S[2,3] P6021[1,2] CT4[1,2]	AM 503S[2,3] P6021[1,2]	AM 503S[2,3] P6021[1,2]	AM 503S[2,3] P6021[1,2] CT1/2[2,3] CT4[1,2]
Fixtured	A6501[2,3] P6501[2,3]		A6501[2,3] P6501[2,3]		
Optical	P6701A[2,3] P6703A[2,3] P6711[2,3] P6713[2,3]		P6701A[2,3] P6703A[2,3] P6711[2,3] P6713[2,3]		P6701A[2,3] P6703A[2,3] P6711[2,3] P6713[2,3]
Time-to-voltage converter	TVC 501[2,3]	TVC 501[2,3]	TVC 501[2,3]	TVC 501[2,3]	

[1]***Qualitative signal evaluation*—use when a great deal of accuracy isn't required, such as in go/no go measurement.**
[2]***Functional testing*—use when the device under test is being compared to some standard.**
[3]***Quantitative Signal Evaluation*—use when detailed evaluation is needed.**

Remote Communication

You may want to integrate your oscilloscope into a benchtop or rack system environment and remotely control your oscilloscope or exchange measurement or waveform data with a computer. You can control your oscilloscope remotely via the IEEE Std 488.2-1987 (GPIB) interface.

Operation

To set up remote communications, you must ensure that your oscilloscope is physically cabled to the controller and that your oscilloscope's parameters are correctly set. Plug an IEEE Std 488.2-1987 GPIB cable (available as Tektronix part number 012-0991-00) into the GPIB connector on your oscilloscope's rear panel and into the GPIB port on your controller (see Figure 3-58).

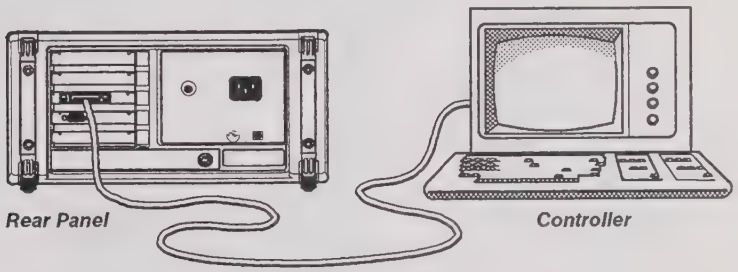


Figure 3-58: Connecting the Digitizing Oscilloscope to a Controller

You set remote communications parameters as follows:

- ☐ **Step 1:** Press the **UTILITY** (**SHIFT** and then **DISPLAY**) button to reach the Utility menu (Figure 3-59).
- ☐ **Step 2:** Select **System** from the main menu. Choose the **I/O** item from the resulting pop-up menu.

Port Selection

Now you need to configure the port to match the controller.

- ☐ **Step 3:** Select **Port** from the main menu.
- ☐ **Step 4:** Select **GPIB** from the Port pop-up menu and **Configure** from the main menu to select the GPIB operating configuration.
- ☐ **Step 5:** Select one of the three GPIB configuration options:
  - Choose **Talk/Listen Address** for normal, controller-based system operation. Use the general purpose knob to define the address.

- Use **Hardcopy (Talk Only)** when you want to use the digitizing oscilloscope's hardcopy port. Once the port is configured this way, the oscilloscope will send the hardcopy data to any listeners on the bus when the **HARDCOPY** button is pressed.

  If the port is configured any other way and the **HARDCOPY** button is pressed, an error will occur and the digitizing oscilloscope will display a message saying the selected hardcopy port is currently unavailable.

- **Off Bus** disconnects the digitizing oscilloscope from the bus.

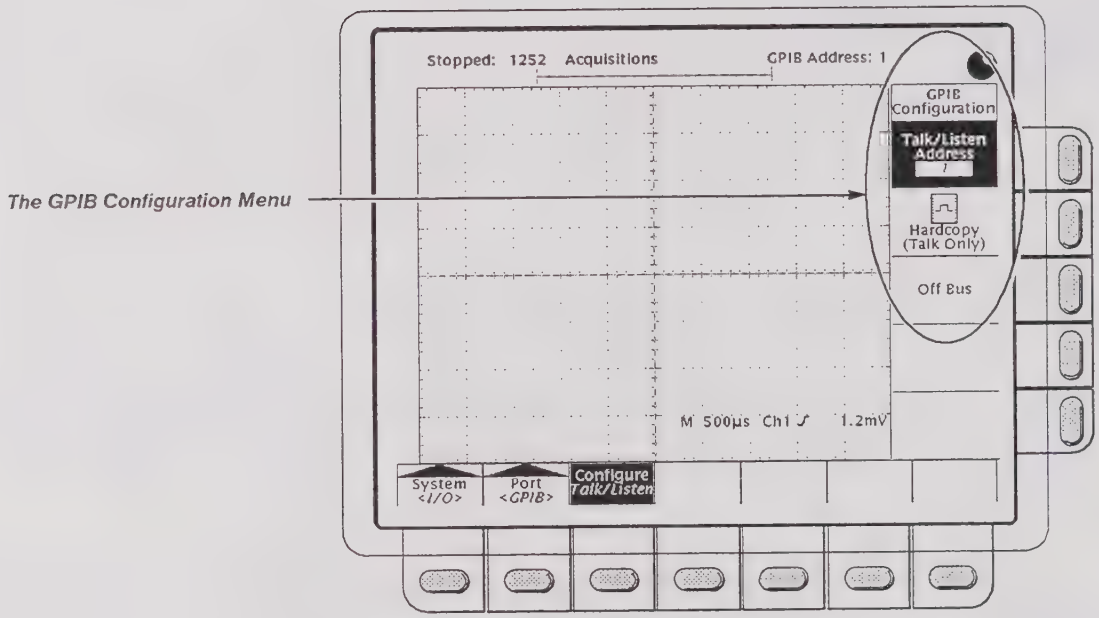


Figure 3-59: Utility Menu

For More Information

See *Remote Communications*, on page 2-31.

See *Hardcopy,* on page 3-41.

See *TDS Family Programmer Manual*, Tektronix part number 070-8318-01.

Saving and Recalling Setups

You may want to save and reuse setups for many reasons. For example, after changing the setting during the course of an experiment, you may want to quickly return to your original setup.

You can save and recall up to ten instrument setups from internal oscilloscope memory. The information is retained even when you turn the oscilloscope off or unplug it.

Operation

To save or recall setups first press the save/recall **SETUP** button to call up the Save/Recall Setup menu (Figure 3-60).

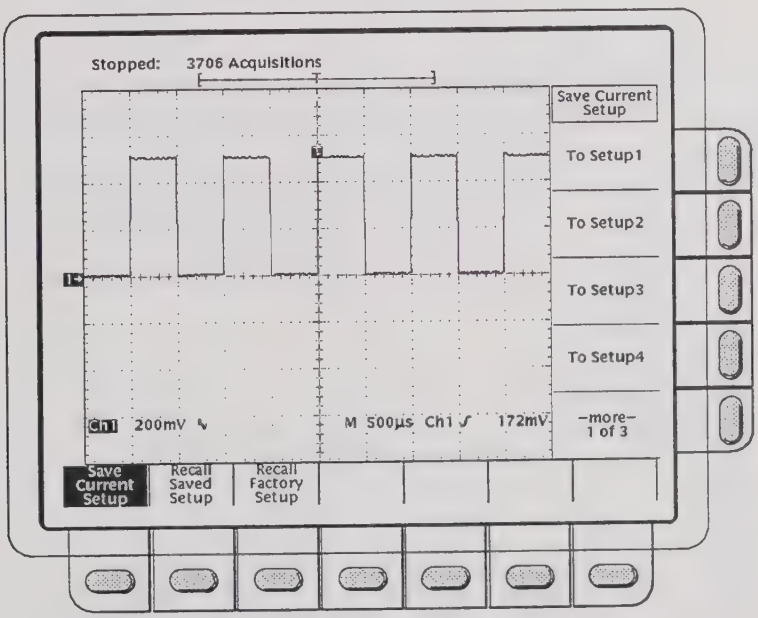


Figure 3-60: Save/Recall Setup Menu

Saving a Setup

To save the digitizing oscilloscope's current setup:

- ☐ **Step 1:** Press the main menu **Save Current Setup** button.
- ☐ **Step 2:** Choose one of the ten storage locations from the side menu (**To Setup 1**, **To Setup 2**, ...). Now the current setup is stored in that particular location.

Recalling a Setup

To recall a setup:

- ☐ **Step 1:** Press the main menu **Recall Saved Setup** button.
- ☐ **Step 2:** Select the side menu item corresponding to the setup location holding the desired setup (**Recall Setup 1**, **Recall Setup 2** ...).

Recalling a setup will not change the menu that is currently displayed.

Recalling the Factory Setup

You may want to reset your oscilloscope to the factory defaults. See *Factory Initialization Settings* on page A-89 for a list of the factory defaults. To recall the factory setup:

- ☐ **Step 1:** Press the main menu **Recall Factory Setup** button.
- ☐ **Step 2:** Press **OK Confirm Factory Init** on the side menu.

For More Information

See *Tutorial Example 4: Saving Setups*, on page 1-19.

See *Save and Document*, on page 2-29.

See *Factory Initialization Settings*, on page A-89.

Saving and Recalling Waveforms

You can store a waveform in one of the digitizing oscilloscope's four internal reference memories. That information is retained even when you turn the oscilloscope off or unplug it. You can save any combination of different size waveform records up to 60,000 record points.

The digitizing oscilloscope can display up to 11 waveforms at one time. That includes waveforms from the four input channels, four reference waveforms, and three math waveforms.

You will find saving waveforms useful when working with many waveforms and channels. If you have more waveforms than you can display, you can save one of the waveforms and then stop acquiring it. That lets you display another waveform without forcing you to loose the first one.

Operation

To save or delete saved waveforms, first press the save/recall **WAVEFORM** button to call up the Save/Recall Waveform menu (Figure 3-61).

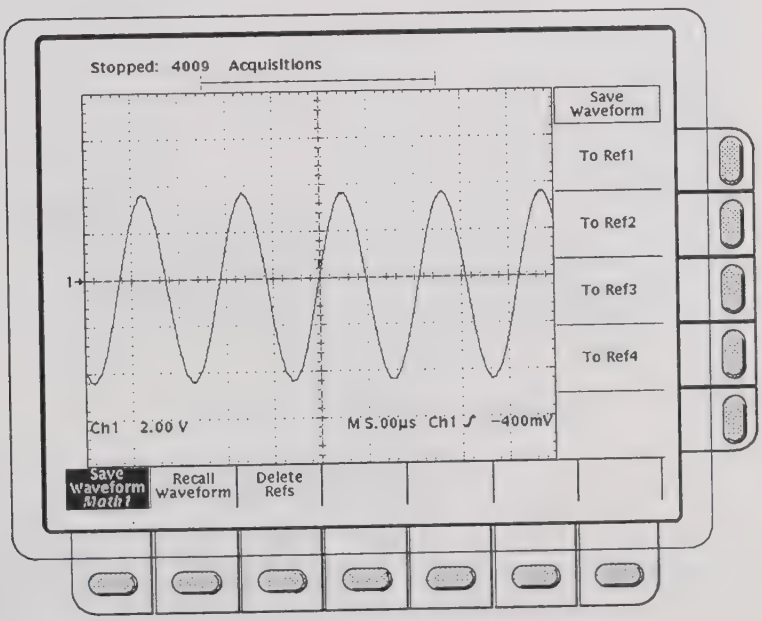


Figure 3-61: Save Waveform Menu

Saving a Waveform

To save a waveform:

☐ **Step 1:** Select the channel that has the waveform you want to save.

☐ **Step 2:** Press the **Save Waveform** main menu button.

☐ **Step 3:** From the side menu, select the reference memory to save the selected waveform to. The side memory lists four references (**To Ref1**, **To Ref2**, **To Ref3**, **To Ref4**).

Deleting Waveforms

If you run out of memory when you try to save a waveform, you can choose the **Delete Refs** main menu item and then select the references you no longer need from the side menu (**Delete Ref1**, **Delete Ref2**, **Delete Ref3**, **Delete Ref4**, or **Delete All Refs**). You'll know if you run out of memory because the digitizing oscilloscope will display an appropriate message.

Recalling a Waveform

You recall waveforms stored in the reference memory through the More main menu.

☐ **Step 1:** Press the **MORE** button to bring up the More menu (Figure 3-62).

☐ **Step 2:** Press the main menu button corresponding to the waveform reference memory to retrieve from (**Ref1**, **Ref2**, **Ref3**, or **Ref4**).

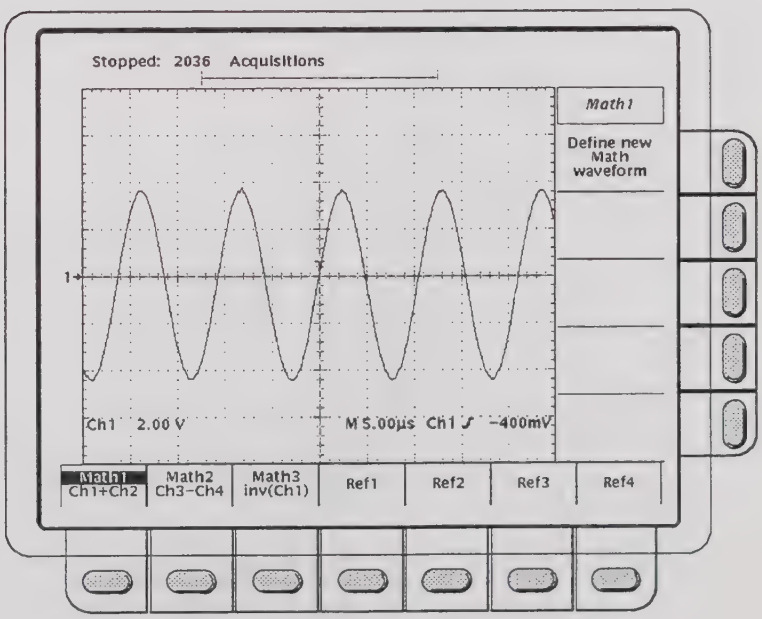


Figure 3-62: More Menu

For More Information

See *Save and Document*, on page 2-29.

See *Selecting Channels*, on page 3-95.

Selecting Channels

The *selected channel* is the channel that the digitizing oscilloscope applies all waveform-specific activities to (such as measurements or vertical scale and position).

Channel Readout

The channel readout shows the selected channel in inverse video in the display's lower left corner (see Figure 3-63).

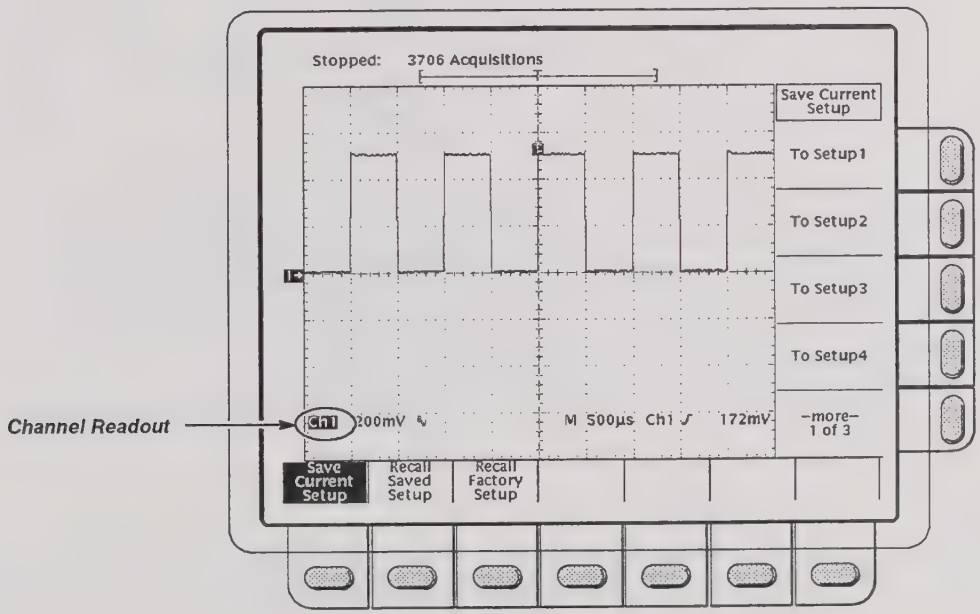


Figure 3-63: The Channel Readout

Channel Selection Buttons

Selecting channels on the TDS 400 series oscilloscopes is straightforward and easy.

The *channel selection* buttons are on the right of the display and are labeled **CH 1**, **CH 2**, **CH 3**, **CH 4**, and **MORE** (Figure 3-64). They determine which channel is selected. The **MORE** button allows you to select internally stored *Math* and *Ref* waveforms for display and manipulation.

The selected channel is indicated by the lighted LED next to each button. Figure 3-64 shows Channel 1 as the currently selected channel.

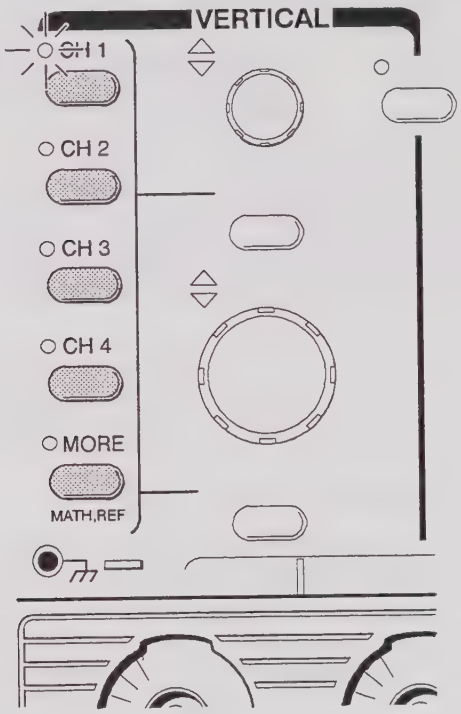


Figure 3-64: Channel Selection Buttons

Operation

Selecting or removing a waveform is as simple as pushing a button.

Selecting a Waveform

Pressing **CH 1, CH 2, CH 3**, or **CH 4** turns the channel on if it is not already on. When you press the **MORE** button, the More menu appears with Math and Ref selections. See *Saving and Recalling Waveforms* on page 3-93 and *Waveform Math* on page 3-117 for information on how to use the More menu.

You do not use the channel selection buttons when triggering. Instead you select the trigger source in the Main Trigger menu or Delayed Trigger menu.

Removing Waveforms From the Display

The **WAVEFORM OFF** button turns OFF the selected channel's waveform display. It will also remove from the display any automated measurements being made on that waveform.

When you turn off a waveform, the digitizing oscilloscope automatically selects the next highest priority waveform. Figure 3-65 shows how the oscilloscope prioritizes waveforms.

1. CH1
2. CH2
3. CH3 (or AUX 1 on the TDS 420)
4. CH4 (or AUX 2 on the TDS 420)

5. MATH1
6. MATH2
7. MATH3

8. REF1
9. REF2
10. REF3
11. REF4

Figure 3-65: Waveform Selection Priority

If you are turning off more than one waveform and you start by turning off a channel waveform, all selected channels will be turned off before going to the MORE waveforms. If you start by turning off the MORE waveforms, all the MORE waveforms will be turned off before going to the channel waveforms.

If you turn off a channel that happens to be a trigger source, the trigger circuitry will continue monitoring that channel even though the waveform is not displayed.

For More Information

See *Saving and Recalling Waveforms,* on page 3-93.

See *Waveform Math,* on page 3-117.

Status

The Status menu lets you see information about the oscilloscope state.

Operation

To operate the Status menu:

☐ **Step 1:** Press the **STATUS** button (**SHIFT** and **HELP**) to bring up the Status side menu (Figure 3-66).

The Status menu is unusual because it only has a side (vertical) menu. There are no choices along the main (horizontal) axis.

☐ **Step 2:** Choose which part of the oscilloscope's operation you want to know about.

- Select **System** from the side menu to display information about the Horizontal, Zoom, Acquisition, Display, Measure, and Hardcopy systems (Figure 3-66). This also tells you what version of firmware the oscilloscope is using.

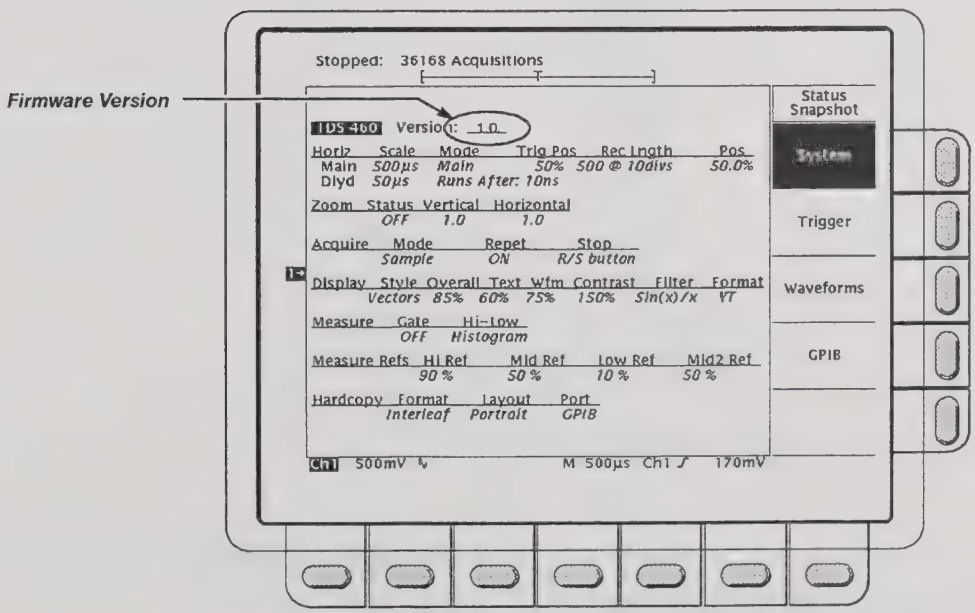

Firmware Version
Stopped: 36168 Acquisitions
TDS 460 Version: 1.0
Horiz Scale Mode Trig Pos Rec Lngth Pos
Main 500µs Main 50% 500 @ 10divs 50.0%
Dlyd 50µs Runs After: 10ns
Zoom Status Vertical Horizontal
OFF 1.0 1.0
Acquire Mode Repet Stop
Sample ON R/S button
Display Style Overall Text Wfm Contrast Filter Format
Vectors 85% 60% 75% 150% Sin(x)/x YT
Measure Gate Hi-Low
OFF Histogram
Measure Refs Hi Ref Mid Ref Low Ref Mid2 Ref
90 % 50 % 10 % 50 %
Hardcopy Format Layout Port
Interleaf Portrait GPIB
Ch1 500mV M 500µs Ch1 170mV
Status Snapshot
System
Trigger
Waveforms
GPIB

Figure 3-66: Status Menu—System

- Select **Trigger** from the side menu to display parameter information about the triggers.

- Select **Waveforms** from the side menu to display information about the various waveforms. That includes live, math, and reference waveforms.
- Select **GPIB** from the side menu to display information about the GPIB system.

Triggering

Triggers determine when the digitizing oscilloscope starts acquiring and displaying a waveform. The TDS 400 series has an edge trigger and an optional video trigger.

Although these two triggers are unique, they have some common characteristics that can be defined and modified using the Trigger menu and the trigger buttons and knob. This article discusses these common characteristics.

To learn more about using specific triggers, see *Edge Triggering* on page 3-35 and *Video Triggering* on page 3-111.

Trigger Button and Knobs

The trigger buttons and knob let you quickly adjust the trigger level or force a trigger (see Figure 3-67).

Figure 3-67: TRIGGER Controls

MAIN LEVEL Knob

The **MAIN LEVEL** knob lets you manually change the trigger level. You adjust the trigger level instantaneously no matter what menu, if any, is displayed.

To Set to 50%

If the trigger type is edge and you press the **SET LEVEL TO 50%** button, the instrument searches for the halfway point between the peaks of the trigger signal and sets the trigger level to that value. When done, the trigger circuitry returns to normal operation.

You can also set the level to 50% in the Trigger menu under the main menu item **Level** if edge is selected.

NOTE

*The **MAIN LEVEL** knob and menu items apply only to the main trigger level. To modify the delayed trigger level, use the Delayed Trigger menu's **Level** item and corresponding side menu.*

Force Trigger

By pressing the **FORCE TRIGGER** front panel button you can force the oscilloscope to immediately start acquiring a waveform record regardless of whether a trigger event occurs.

The oscilloscope recognizes and acts upon **FORCE TRIGGER** even when you press it before the end of pretrigger holdoff. However, the button has no effect if the acquisition system is stopped.

If your goal is to act on the next valid trigger event and then stop, use the Acquire menu's **Single Acquisition Sequence** option. To use that feature, press the **ACQUIRE MENU** button (**SHIFT** and then **RUN/STOP**) followed by the main menu's **Stop After** selection. Finally, select **Single Acquisition Sequence** from the side menu. Now you can initiate the single sequence of acquisitions by pressing the **RUN/STOP** button.

Readouts

The digitizing oscilloscope has display readouts and status lights dedicated to monitoring the trigger circuitry.

Trigger Status Lights

There are three status lights in the Trigger control area (see Figure 3-68) indicating the state of the trigger circuitry. The lights are labeled **TRIG'D**, **READY**, and **ARM**.

- When **ARM** is lighted, it means the trigger circuitry is filling the pretrigger portion of the waveform record.
- When **READY** is lighted, it means the digitizing oscilloscope can accept a valid trigger event and it is waiting for that event to occur.
- When **TRIG'D** is lighted, it means the digitizing oscilloscope has recognized a valid trigger and is filling the posttrigger portion of the waveform.

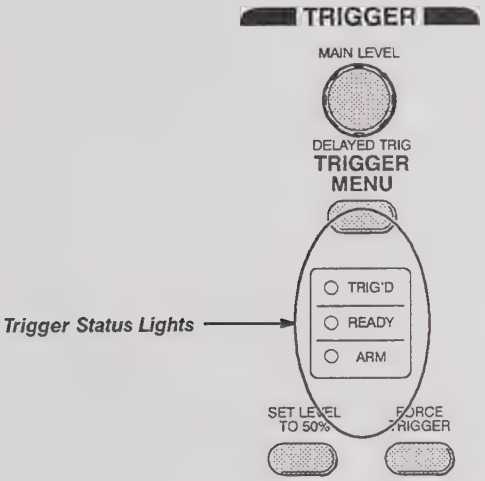


Figure 3-68: Trigger Status Lights

Trigger Display Readout

At the bottom of the display, the Trigger readout shows some the edge trigger's key parameters (Figure 3-69).

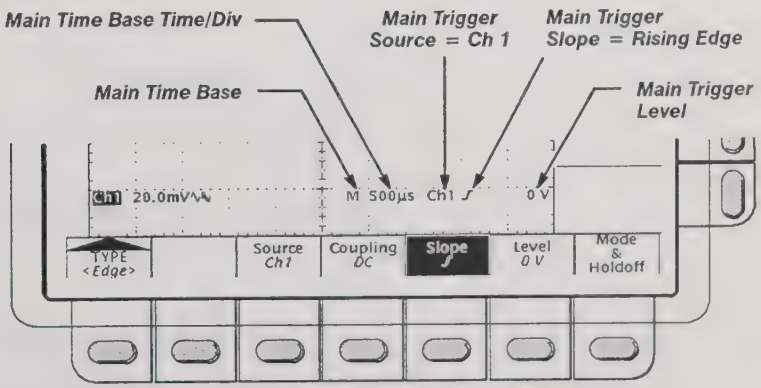


Figure 3-69: Example Trigger Readouts

The record view at the top of the display shows the location of the trigger signal in the waveform record and with respect to the display (see Figure 3-70).

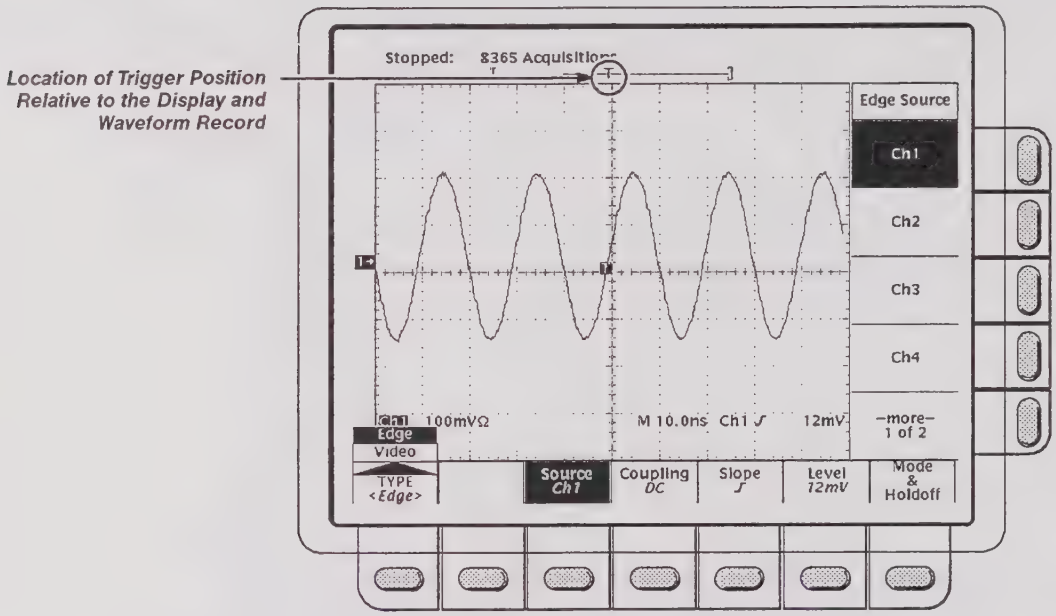


Figure 3-70: Record View Readout Showing Trigger Position

Trigger Menu

There are several trigger selections in the Main Trigger menu that are common to the trigger types. They are **Type**, **Source**, and **Mode & Holdoff**.

Type

To select the trigger type:

- ☐ **Step 1:** Press the **TRIGGER MENU** button to call up the Main Trigger menu.
- ☐ **Step 2:** Select the appropriate trigger type (**Edge** or **Video**).

Source

You need to select which source you want the trigger circuitry to monitor.

- ☐ **Step 1:** Choose the source by selecting the main menu **Source** item.
- ☐ **Step 2:** In the side menu, select one of the available channels.

Mode & Holdoff

You can change the holdoff time and select the trigger mode using this menu. See Triggering on page 2-5 for more details on mode and holdoff.

☐ **Step 1:** Press the **Mode & Holdoff** in the main menu.

☐ **Step 2:** To set the mode, press either **Auto** or **Normal**.

- In **Auto** mode the oscilloscope acquires a waveform after a specified time has elapsed even if a trigger doesn't occur. The amount of time the oscilloscope waits depends on the time base setting.
- In **Normal** mode the oscilloscope acquires a waveform only if there is a valid trigger.

☐ **Step 3:** To change the holdoff time, select the **Holdoff** side menu item. Enter the value in % using the general purpose knob. If you want to enter a large number using the general purpose knob, press the **SHIFT** button before turning the knob. When the light next to the **SHIFT** button is on and the display says **Coarse Knobs** in the upper right corner, the general purpose knob speeds up significantly.

Holdoff is automatically reset to 0% when you change the main time base time/division setting. However, it is not reset if you change the delayed time base time/division (that is, when the time base setting in the Horizontal menu is **Intensified** or **Delayed Only**).

For More Information

See *Edge Triggering*, on page 3-35.

See *Triggering*, on page 2-5.

See *Video Triggering*, on page 3-111.

Vertical Control

You can control the vertical position and scale of the selected waveform using the vertical menu and knobs.

Vertical Knobs

By changing the vertical scale, you can focus on a particular portion of a waveform. By adjusting the vertical position, you can move the waveform up or down on the display. That is particularly useful when you are comparing two or more waveforms.

To change the vertical scale and position, use the vertical **POSITION** and vertical **SCALE** knobs. The vertical controls (see Figure 3-71) only affect the selected waveform.

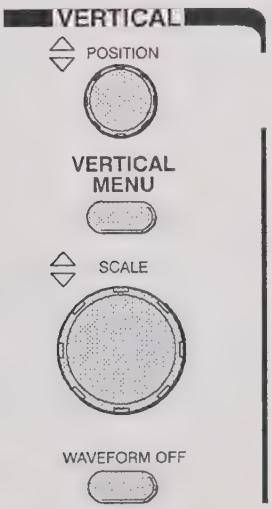


Figure 3-71: Vertical Controls

The **POSITION** knob simply adds screen divisions to the selected waveform's reference point. Adding divisions moves the waveform up and subtracting them moves the waveform down. You also can adjust the waveform's position using the Vertical menu's offset option (discussed later in this article).

If you want the **POSITION** knob to move faster, press the **SHIFT** button. When the light next to the **SHIFT** button is on and the display says **Coarse Knobs** in the upper right corner, the **POSITION** knob speeds up significantly.

The *Vertical readout* at the lower part of the display shows each displayed channel (the selected channel is in inverse video), and its volts/division setting (see Figure 3-72).

Vertical Readouts

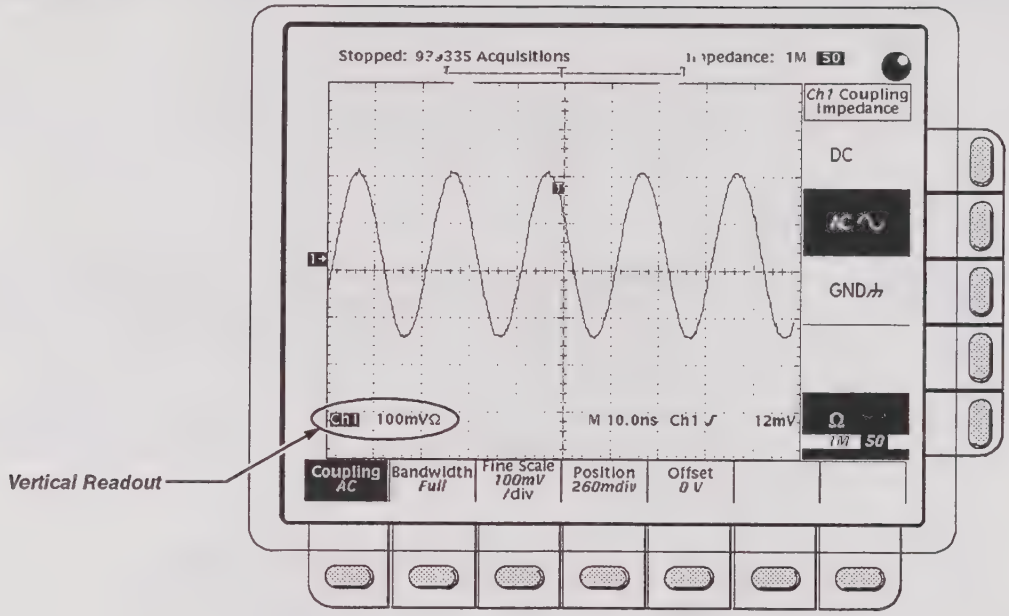


Figure 3-72: Vertical Readouts

Vertical Menu

The Vertical menu lets you select the coupling, bandwidth, and offset for the selected waveform. It also lets you numerically change the position or scale instead of using the vertical knobs.

Press the **VERTICAL MENU** button to call up the menu (Figure 3-73).

Coupling

You can choose the type of vertical coupling for the selected channel and its input impedance.

☐ **Step 1:** Select **Coupling** in the main menu to select the vertical coupling method for attaching the input signal to the vertical attenuator.

☐ **Step 2:** This menu lets you choose between AC, DC, or Ground (GND) coupling. You also can set input impedance.

DC
- **DC** coupling shows both the AC and DC components of an input signal.

AC ∿
- **AC** coupling show only the alternating components of an input signal.

GND
- Ground (**GND**) coupling disconnects the input signal from the acquisition.

Ω
- Input impedance lets you select either 1 MΩ or 50 Ω impedance.

NOTE

If you select 50 Ω impedance with AC coupling, the digitizing oscilloscope will not accurately display frequencies under 200 kHz.

Also, when you connect an active probe to the oscilloscope (such as the P6205), the input impedance of the oscilloscope automatically becomes 50 Ω. If you then connect a passive probe (like the P6138) you need to set the input impedance back to 1 MΩ.

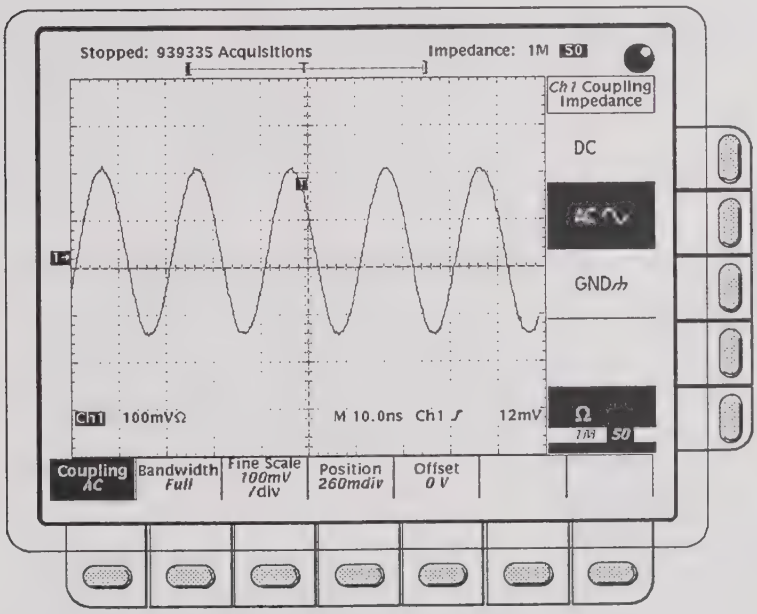


Figure 3-73: Vertical Channel Menu

Bandwidth

You can change the bandwidth of the selected channel if you want to eliminate the higher frequency components.

Select the **Bandwidth** to select one of the bandwidth filters.

You can choose **Full**, **100 MHz,** or **20 MHz** bandwidth settings.

Fine Scale

Select the main menu **Fine Scale** item to make fine adjustments to the vertical scale using the general purpose knob. The side menu item shows the setting of the **Fine Scale** parameter. That readout and the display's vertical readout will show any changes to the volts/division.

Position

Press the main menu item **Position** to let the general purpose knob control the vertical position. Toggle the **Set to Zero** selection if you want to reset the selected waveform's reference point to the center of the display.

Offset

Offset lets you add DC bias to the waveform, so the oscilloscope can acquire the exact part of the waveform you are interested in.

Offset if very useful when you want to examine a waveform with a DC bias. For example, you might be trying to look at a small ripple on a power supply output. It may be a 100 mV ripple on top of a 15 V supply. With offset's range you can display the ripple and scale it to meet your needs.

To use offset, select **Offset** in the main menu. Use the general purpose knob to control the vertical offset. Toggle the **Set to Zero** selection if you want to reset the offset to zero.

For More Information

See *Acquisition*, on page 2-13

See *Scaling and Positioning Waveforms,* on page 2-21.

Video Triggering

The optional Video Trigger menu gives you a variety of selections for triggering on a video signal.

A *video trigger* event occurs when a video signal generates a horizontal or vertical sync pulse. For more information, see *Triggering* on page 2-5.

Operation

The Video Trigger menu lets you select the source, polarity, class, mode, and holdoff. It also gives you the option to delay by lines or time and lets you trigger on the first field, second field, or both.

To bring up the Video Trigger menu:

- ☐ **Step 1:** Press the **TRIGGER MENU** button to bring up the Main Trigger menu.
- ☐ **Step 2:** Press **Type** in the main menu until you select **Video** from the pop-up menu (see Figure 3-74).

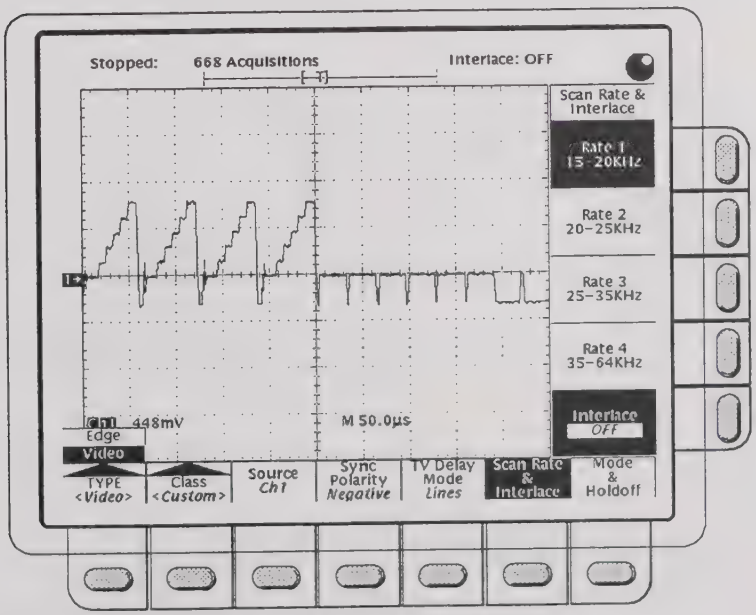


Figure 3-74: Main Trigger Menu—Video Type

Video Class

Using the Class option you can select predefined setups (NTSC, PAL, or SECAM) or customize the setup.

☐ **Step 1:** Press the main menu **Class** button until you select the setup you want (Figure 3-75).

- **NTSC** has a line rate of 525 lines per frame and a field rate of 60 Hz.
- **PAL** has a line rate of 625 lines per frame and a field rate of 50 Hz.
- **SECAM** has a line rate of 625 lines per frame and a field rate of 50 Hz.
- **Custom** lets you specify the frequency range of the video signal. The different ranges are listed in the Scan Parameter side menu (discussed further on in this article).

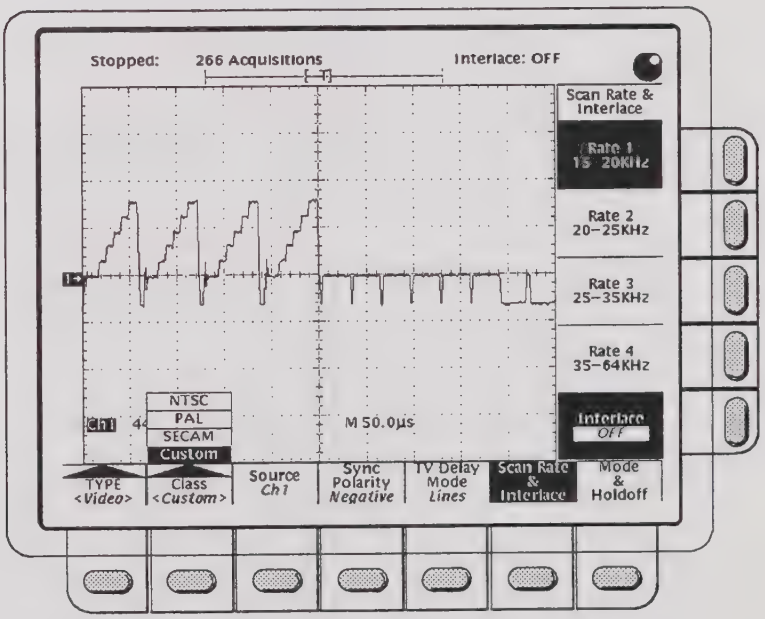


Figure 3-75: Video Trigger Menu—Class

Source

You need to select which source you want the trigger to come from.

☐ **Step 1:** Choose the video source by selecting the main menu **Source** item.

☐ **Step 2:** Select one the four available channels in the side menu (**Ch1**, **Ch2**, **Ch3**, or **Ch4**).

Sync Polarity

Negative polarity is the standard for horizontal and vertical synch pulses. However, you may want to trigger on a positive polarity pulse when probing circuitry that inverts the video signal. You can easily change the polarity by using the **Sync Polarity** option.

☐ **Step 1:** Select the main menu **Sync Polarity** item.

☐ **Step 2:** Choose between **Neg Sync** and **Pos Sync**.

TV Delay Mode

You specify the delay for a video trigger with the **TV Delay Mode** option. Since video signals are composed of line information and other time specified components, the **TV Delay Mode** option lets you delay by lines or time (see Figure 3-76).

☐ **Step 1:** Press the main menu **TV Delay Mode**.

☐ **Step 2:** From the side menu, select **Delay by Lines** or **Delay by Time**. Use the general purpose knob to enter the value.

If you want to enter a large number using the general purpose knob, press the **SHIFT** button before turning the knob. When the light next to the **SHIFT** button is on and the display says **Coarse Knobs** in the upper right corner, the general purpose knob speeds up significantly.

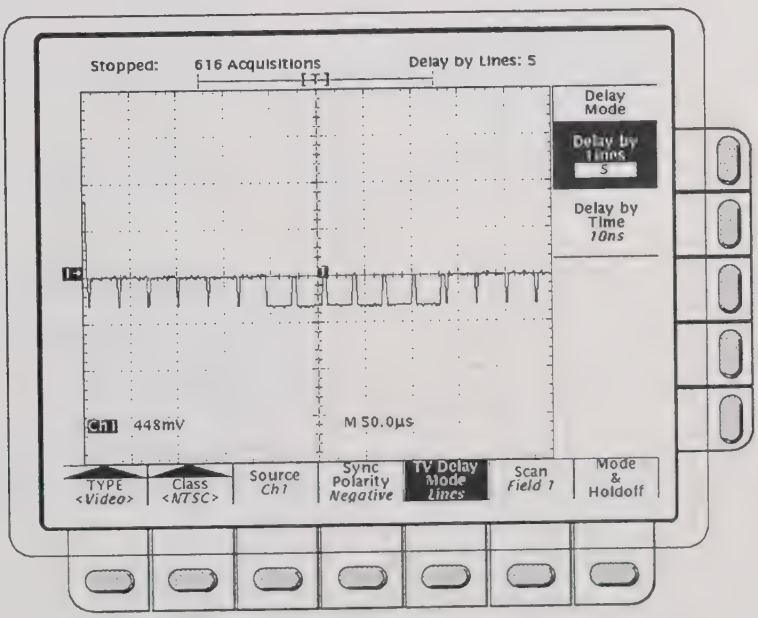


Figure 3-76: Video Trigger Menu—TV Delay Mode

Scan

If you selected **NTSC**, **PAL**, or **SECAM** in the Class menu, there is a Scan menu that lets you choose between triggering on the first field, the second field, or both.

☐ **Step 1:** Press the main menu **Scan** (see Figure 3-77).

☐ **Step 2:** The Scan menu lets you trigger on field one, field two, or both fields.

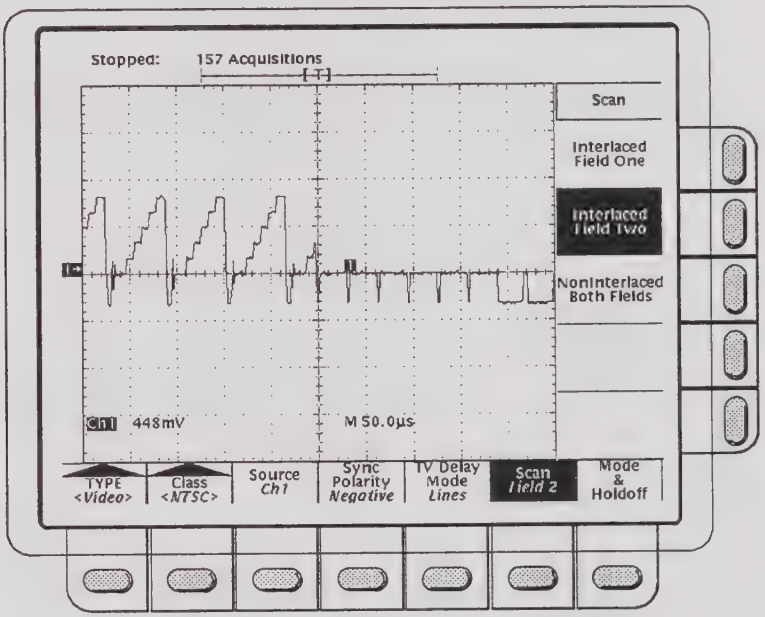


Figure 3-77: Video Trigger—Scan Parameter

- If you choose **Interlaced Field One**, the digitizing oscilloscope will always trigger on the start of the first field in an interlaced frame.
- If you choose **Interlaced Field Two**, the digitizing oscilloscope will always trigger on the first line of the second field in an interlaced frame.
- If you choose **NonInterlaced Both Fields**, the digitizing oscilloscope alternates between triggering on the start of field one and field two.

Scan Rate & Interlace

If you selected **Custom** in the Class menu, the Scan Rate & Interlace option will list several frequency range options (see Figure 3-78).The options are: **Rate 1** (15–20 kHz), **Rate 2** (20–25 kHz), **Rate 3** (25–35 kHz), and **Rate 4** (35–64 kHz).

By toggling the button next to the **Interlaced** option, you can trigger on interlaced field one, interlaced field two, or both fields noninterlaced.

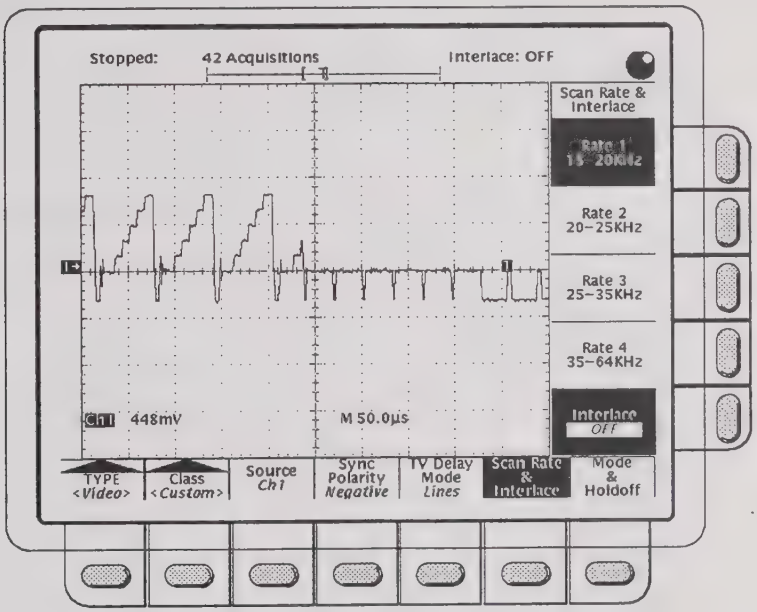


Figure 3-78: Video Trigger – Scan Rate & Interlace

Mode & Holdoff

You can change the holdoff time and select the trigger mode using this menu item. See Triggering on page 2-5 for more details on mode and holdoff.

☐ **Step 1:** Select the **Mode & Holdoff** item in the main menu (see Figure 3-79).

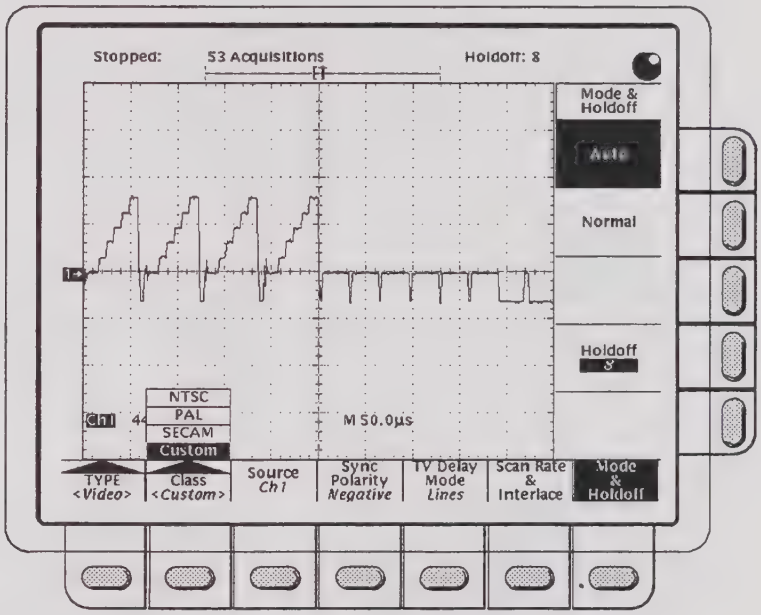


Figure 3-79: Video Trigger Menu—Mode & Holdoff

☐ **Step 2:** To set the mode, press either **Auto** or **Normal**.

- In **Auto** mode the oscilloscope acquires a waveform even if a trigger doesn't occur.
- In **Normal** mode the oscilloscope acquires a waveform only if there is a valid trigger.

☐ **Step 3:** To change the holdoff time, press the **Holdoff**. Enter the value using the general purpose knob. If you want to enter a large number, press the **SHIFT** button before turning the knob. When the light next to the **SHIFT** button is on and the display says **Course Knobs** in the upper right corner, the general purpose knob speeds up significantly.

There are different default values for holdoff to insure a stable color burst in the sync pulse. These holdoff values depend on whether you select **NTSC**, **PAL**, or **SECAM** and if you trigger on interlaced field one or two.

For More Information

See *Triggering*, on page 2-5.

Waveform Math

You can mathematically manipulate your waveforms. For example, you might have a waveform clouded by background noise. You can obtain a cleaner waveform by subtracting the background noise from your original waveform.

Operation

To perform waveform math press the **MORE** button to bring up the More menu (Figure 3-80). The More menu allows you to display, define, and manipulate math functions.

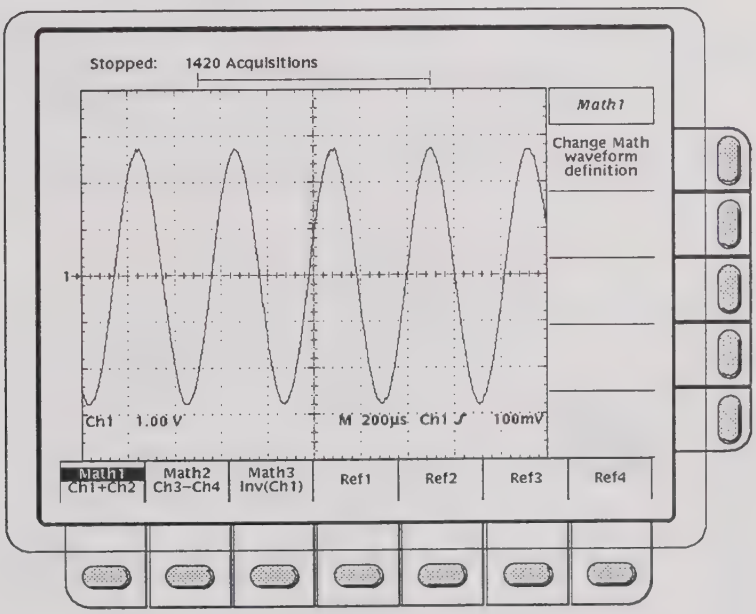


Figure 3-80: More Menu

Math1, Math2, and Math3

- **Step 1:** Select the main menu item corresponding to the math waveform you wish to display or change. You can choose **Math1**, **Math2**, or **Math3** (Figure 3-80).
- **Step 2:** Press the side menu item **Change Math waveform definition** to bring up a second set of main and side menus to alter the present math waveform definition (Figure 3-80).
- **Step 3:** Select **Single Wfm Math** or **Dual Wfm Math** from the main menu (see Figure 3-81).

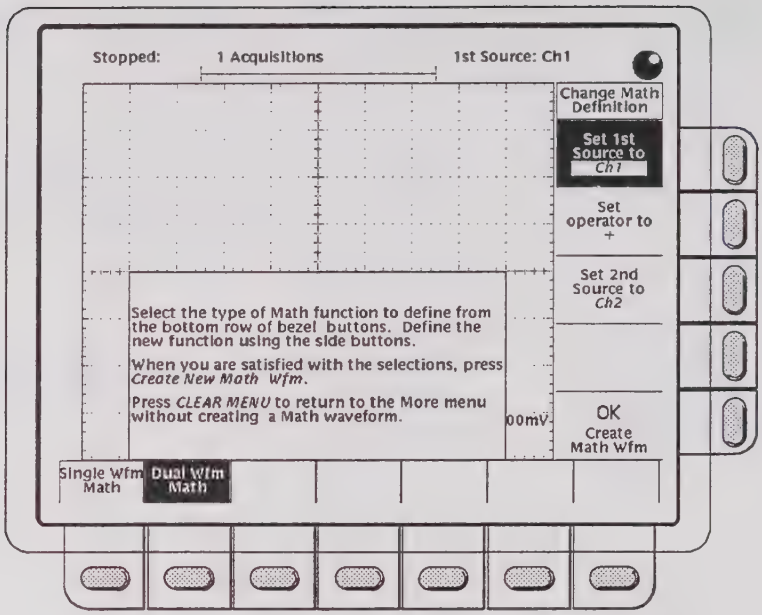

Stopped:
1 Acquisitions
1st Source: Ch1
Change Math Definition
Set 1st Source to Ch1
Set operator to +
Set 2nd Source to Ch2
Select the type of Math function to define from the bottom row of bezel buttons. Define the new function using the side buttons.
When you are satisfied with the selections, press Create New Math Wfm.
Press CLEAR MENU to return to the More menu without creating a Math waveform.
00mV
OK Create Math Wfm
Single Wfm Math
Dual Wfm Math

Figure 3-81: Dual Waveform Math Main and Side Menus

Single Wfm Math

☐ **Step 1:** For Single Wfm Math, you can select **Set Function to**. The only argument choice is **inv** (invert). This takes the inverse of the source waveform.

☐ **Step 2:** You can define the source waveform by toggling the **Set Single Source to** item or by selecting that item and using the general purpose knob.

☐ **Step 3:** When you're ready to perform the function, select the **OK Create Math Wfm**.

Dual Wfm Math

☐ **Step 1:** For Dual Wfm Math, you select the sources with the **Set 1st Source to** and **Set 2nd Source to** options. Enter the sources by pressing the appropriate channel selection button or by using the general purpose knob.

☐ **Step 2:** Enter the math operator to use on the sources by selecting the **Set operator to**. Enter the operator by toggling the button next to this side menu selection or by turning the general purpose knob. Supported operators are +, –, and *.

☐ **Step 3:** Press the **OK Create Math Wfm** option to perform the function.

Zoom

At times, you may want to expand or compress a waveform on the display without changing the acquisition parameters. You can do that with the zoom feature.

Operation

When you turn on the zoom feature, the vertical and horizontal scale and position controls cease to have any effect on the acquisition hardware. Instead, they control the displayed size and position of waveforms, allowing them to be expanded and repositioned on screen.

To use zoom:

☐ **Step 1:** Press the **ZOOM** button. The Zoom side menu will appear (Figure 3-82).

The Zoom menu is unusual because it only has a side (vertical) menu. There are no choices along the main (horizontal) axis.

Waveforms at their pre-zoom size.

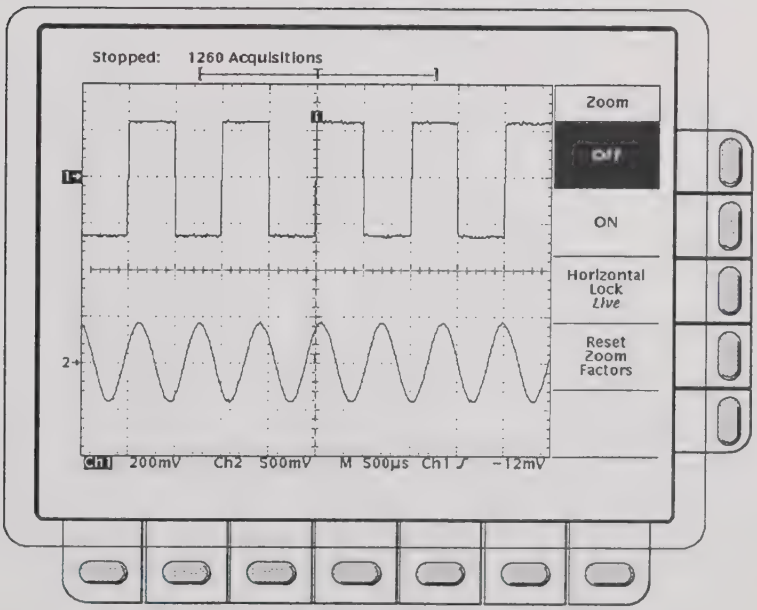


Figure 3-82: Zoom Menu

☐ **Step 2:** Select the side menu **ON** item. The **ZOOM** front-panel button should light up.

NOTE

When you zoom, the display redraws the waveforms using the interpolation method you selected in the Display menu (linear interpolation or sin(x)/x). If you selected sin(x)/x it may introduce some overshoot or undershoot to the waveform's edges. If that happens, change the interpolation method to linear.

For information on how to change the interpolation method, see Display Modes on page 3-29.

Horizontal Lock

You can choose to use zoom only on the selected waveform or you can zoom in on all displayed waveforms using the **Horizontal Lock** side menu item.

☐ **Step 3:** If you toggle **Horizontal Lock** to **None**, only the selected waveform is affected by horizontal zoom changes (Figure 3-83). If you toggle **Horizontal Lock** to **Live**, all displayed waveforms are magnified and positioned together (Figure 3-84). That is, they all have the same zoom parameters.

You can also use the general purpose knob to change the **Horizontal Lock** from **None** to **Live**.

Only the selected waveform (the top one) changes size.

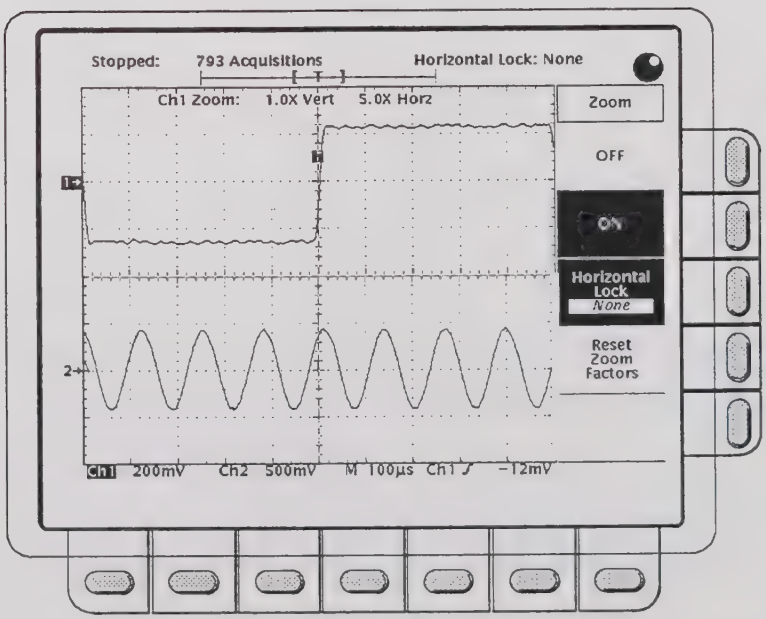


Figure 3-83: Zoom Mode with Horizontal Lock Set to None

All displayed waveforms change size

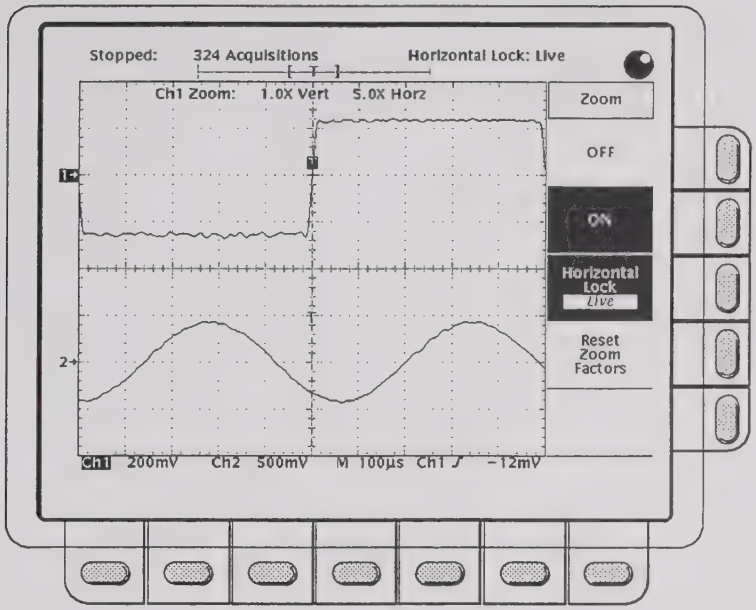


Figure 3-84: Zoom Mode with Horizontal Lock Set to Live

Reset Zoom

To reset all zoom factors to their defaults, press the **Reset Zoom Factors** side menu choice. The defaults are as follows:

Table 3-7: Zoom Defaults

Parameter	Setting
Zoom Vertical Position	0
Zoom Vertical Gain	1X
Zoom Horizontal Position	Tracking Horizontal Position
Zoom Horizontal Gain	1X

☐ **Step 4:** Select **Off** to return to normal oscilloscope (non-zoom) operation.

Appendices

Replace this page with the tab divider of the same name.

Appendix A: Options and Accessories

This section describes the various options as well as the standard and optional accessories that are available for the TDS 420 and TDS 460 Digitizing Oscilloscopes.

Options

Options include:

Options 05: Video Trigger

This option provides a video trigger. It lets you trigger on positive or negative sync pulses. It also lets you select interlaced field one, interlaced field two, or both fields noninterlaced. You can define the signal's class to be NTSC, PAL, SECAM, or you can customize the class.

Options A1–A5: International Power Cords

Besides the standard North American, 110 V, 60 Hz power cord, Tektronix ships any of five alternate power cord configurations with the oscilloscope when ordered by the customer.

Table A-1: International Power Cords

Option	Power Cord
A1	Universal European—220 V, 50 Hz
A2	UK—240 V, 50 Hz
A3	Australian—240 V, 50 Hz
A4	North American—240 V, 60 Hz
A5	Switzerland—220 V, 50 Hz

Option B1: Module Level Service Manual

When Option B1 is ordered, Tektronix ships a module level service manual with the oscilloscope.

Option 1M: 30,000 Point Record Length

This option provides a maximum record length of 30,000 points per acquisition (30,000/channel).

Warranty-Plus Service Options

The following options add to the services available with the standard warranty. (The standard warranty appears on the back side of the title page in this manual.)

- **Option M2:** When Option M2 is ordered, Tektronix provides five years of warranty/remedial service.
- **Option M3:** When Option M3 is ordered, Tektronix provides five years of warranty/remedial service and four oscilloscope calibrations.
- **Option M8:** When Option M8 is ordered, Tektronix provides four calibrations and four performance verifications, one of each in the second through the fifth years of service.

Option 1P: HC100 4 Pen Plotter

With this option, Tektronix ships a four-color plotter designed to make waveform plots directly from the digitizing oscilloscope without requiring an external controller. It handles A4 and US letter size media.

Option 1R: Rackmounted Digitizing Oscilloscope

Tektronix ships the digitizing oscilloscope, when ordered with Option 1R, configured for installation in a 19 inch wide instrument rack. Customers with instruments not configured for rackmounting can order a rackmount kit (016-1166-00) for field conversions.

Instructions for rackmounting the digitizing oscilloscope are shipped with the option 1R.

Option 22: Additional Probes

With this option, Tektronix ships two additional probes identical to the two standard-accessory P6138 probes normally shipped with the instrument. This provides one probe for each front-panel input.

Option 23: Active Probes

With this option, Tektronix ships two active high speed voltage probes (the P6205 10X FET).

Option 9C: Certificate of Calibration and Test Data Report

Tektronix ships a Certificate of Calibration which states this instrument meets or exceeds all warranted specifications and has been calibrated using standards and instruments whose accuracies are traceable to the National Institute of Standards and Technology, an accepted value of a natural physical constant or a ratio calibration technique. The calibration is in compliance with US MIL-STD-45662A. This option also includes a test data report for the instrument.

Standard Accessories

The following standard accessories are included with the digitizing oscilloscope:

Table A-2: Standard Accessories

Accessory	Part Number
Tutorial/User Manual	070-8034-00
Programmer Manual	070-8318-01
Quick Reference	070-8035-00
U.S. Power Cord	161-0230-01
Probes (qty. two) P6138 10X Passive	P6138 (single unit)

Probe Accessories

These are accessories to the standard probe listed previously (P6138). Except for the probe-tip-to-circuit board adapter, they can also be ordered separately.

Table A-3: Probe Accessories

Accessory	Part Number
Retractable Hook Tip	013-0107-06
Body Shell, tip cover	204-1049-00
Probe-Tip-to-Circuit Board Adapter (qty. two standard, optionally available in package of 25 as 131-5031-00)	No customer orderable part number for double unit
6-Inch Slip-On Ground Lead	196-3113-02
Low Inductance Ground Lead	195-4240-00
Marker Rings Set (qty. eighteen rings which includes two each of nine colors)	016-0633-00
Ground Collar	343-1003-01
6-Inch Alligator Clip Ground Lead	196-3305-00
Screwdriver: adjustment tool, metal tip	003-1433-00
SMT KlipChip™	206-0364-00
Accessory Pouch	016-0708-00

Optional Accessories

You can also order the following optional accessories:

Table A-4: Optional Accessories

Accessory	Part Number
TDS 420 Module Level Service Manual	070-8036-00
TDS 460 Module Level Service Manual	070-8037-00
Oscilloscope Cart	K212
Rackmount Kit (for field conversion)	016-1166-00
Oscilloscope Camera	C9
Oscilloscope Camera Adapter	016-1154-00
Soft-Sided Carrying Case	016-1158-00
Transit Case	016-1157-00
GPIB Cable (1 meter)	012-0991-01
GPIB Cable (2 meter)	012-0991-00
Security Cable	012-1388-00
Front Cover	200-3232-00
Pouch	016-1159-00
VGA Cable	73893013 (NEC part number)

Accessory Probes

The following optional accessory probes are recommended for use with your digitizing oscilloscope:

- P6101A 1X, 15 MHz, Passive probe.
- P6156 10X, 3.5 GHz, Passive, low capacitance, (low impedance Zo) probe. Option 25 provides 100X.
- P6009 Passive, high voltage probe, 100X, 1500 VDC + Peak AC
- P6015A Passive high voltage probe, 1000X, 20 kVDC + Peak AC (40 kV peak for less than 100 ms)
- P6205 750 MHz probe bandwidth. Active (FET) voltage probe.
- P6204 Active, high speed digital voltage probe. FET. DC to 1 GHz. DC offset. 50 Ω input. Use with 1103 TekProbe Power Supply for offset control.
- P6046 Active, differential probe, 1X/10X, DC to 100 MHz, 50 Ω input.
- A6501 Buffer Amplifier (active fixtured), 1 GHz, 1 MΩ, 10X.
- P6501 Option 02: Microprobe with TekProbe power cable (active fixtured), 750 MHz, 1 MΩ, 10X.
- AM 503S – DC/AC Current probe system, AC/DC. Uses A6302 Current Probe.
- AM 503S Option 03: DC/AC Current probe system, AC/DC. Uses A6303 Current Probe.
- P6021 AC Current probe. 120 Hz to 60 MHz.
- P6022 AC Current probe. 935 kHz to 120 MHz.
- CT-1 Current probe – designed for permanent or semi-permanent in-circuit installation. 25 kHz to 1 GHz, 50 Ω input.
- CT-2 Current probe – designed for permanent or semi-permanent in-circuit installation. 1.2 kHz to 200 MHz, 50 Ω input.
- CT-4 Current Transformer – for use with the AM 503S (A6302) and P6021. Peak pulse 1 kA. 0.5 Hz to 20 MHz with AM 503S (A6302).
- P6701A Opto-Electronic Converter, 500 to 950 nm, DC to 850 MHz 1 V/mW.
- P6703A Opto-Electronic Converter, 1100 to 1700 nm, DC to 1 GHz 1 V/mW.
- P6711 Opto-Electronic Converter, 500 to 950 nm, DC to 250 MHz 5 V/mW.
- P6713 Opto-Electronic Converter, 1100 to 1700 nm, DC to 300 MHz. 5 V/mW.
- TVC 501 Time-to-voltage converter. Time delay, pulse width and period measurements.
- P6562 SMT Probe, 350 MHz.

Probe Accessories

The following optional accessories are recommended for use with the standard probe listed under *Standard Accessories.*

Table A-5: Probe Accessories

Accessory	Part Number
Connector, BNC: BNC to Probe Tip Adapter	013-0226-00
Connector, BNC: 50 Ω, BNC to Probe Tip Adapter	013-0227-00
Connector, Probe: Package of 100, compact	131-4244-00
Connector, Probe: Package of 25, compact	131-5031-00
Screwdriver Adjustment Tool, Package of five	003-1433-01
Compact-to-Miniature Probe Tip Adapter	013-0202-02
Probe Tip Holder: (holds three tips)	352-0670-00
3 Inch Slip-On Ground Lead	196-3113-03
Probe Holder: Black ABS	352-0351-00
IC Protector Tip, Package of 10	015-0201-07
IC Protector Tip, Package of 100	015-0201-08
Marker Ring Set: Two each of nine colors	016-0633-00
SMT KlipChip™: 20 Adapters	SMG50
Low-Inductance Spring-Tips: Two each of five different springs and insulator	016-1077-00
Probe Tip-to-Chassis Adapter	131-4210-00
NOTE *The next four items below can only be used with the Compact-to-Miniature Probe Tip Adapter.*	
Dual-Lead Adapter	015-0325-00
BNC-to-Probe Tip Adapter	013-0084-01
G.R.-to-Probe Tip Adapter, 50 Ω	017-0088-00
Bayonet Ground Assembly	013-0085-00

Accessory Software

The following optional accessories are Tektronix software products recommended for use with your digitizing oscilloscope:

Table A-6: Accessory Software

Software	Part Number
EZ-Test Program Generator	S45F030
Wavewriter: AWG and waveform creation	S3FT400
TekTMS: Test management system	S3FT001
LabWindows	S3FG910

Warranty Information

Check for the full warranty statements for this product, the probes, and the products listed above on the back of each product manual's title page.

Appendix B: Specification

This subsection begins with a general description of the traits of the TDS 400 Digitizing Oscilloscopes. Three subsections follow, one for each of three classes of traits: *nominal traits, warranted characteristics,* and *typical characteristics*.

General

The Tektronix TDS 400 Digitizing Oscilloscopes are portable, four-channel instruments suitable for use in a variety of test and measurement applications and systems. The TDS 420 has an analog bandwidth of 150 MHz; the TDS 460 has an analog bandwidth of 350 MHz.

Key features include:

- Simultaneous acquisition of waveforms in all four channels at the maximum digitizing rate of 100 Megasamples/second. All channels acquire at full analog bandwidth.
- Four input channels, each with a record length of 500 to 5,000 points and 8-bit vertical resolution. (Option 1M extends the maximum record length to 30,000 points.)
- Video triggering capabilities (with Option 5, Video Trigger).
- Full programmability and printer/plotter output.
- Advanced functions, such as continuously updated measurements.
- Specialized display modes, such as infinite and variable persistence.
- A unique graphical user interface (GUI), an on-board help mode, and a logical front-panel layout which combine to deliver a new standard in usability.

User Interface

This digitizing oscilloscope uses a combination of front-panel buttons, knobs, and on-screen menus to control its many functions. The front-panel controls are grouped according to function: vertical, horizontal, trigger, and special. Within each group, any function likely to get adjusted often, such as vertical positioning or the time base setting, is set directly by its own front-panel knob.

Menus

Those functions for which control settings are usually changed less often, such as vertical coupling and horizontal mode, are set indirectly. That is, pressing one (sometimes two) front-panel button, such as vertical menu, displays a menu of functions at the bottom of the screen that are related to that button. (For the button vertical menu, the menu displayed contains the

functions such as coupling and bandwidth.) Using the buttons below this *main* menu to select a function, such as coupling, displays a *side* menu of settings for that function, such as AC, DC, or GND (ground) coupling, at the right side of the screen. Use the buttons to the right of the menu to select a setting, such as DC.

Indicators

Several on-screen readouts help you keep track of the settings for various functions, such as vertical and horizontal scale and trigger level. There are also readouts to display the results of measurements made using cursors or using the automatic parameter extraction feature (called measure) and readouts to display the status of the instrument.

General Purpose Knob

Menus can also be used to assign the general purpose knob to adjust a selected parameter function. The method employed is the same as for *selecting* a function, except the final selection in the side menu causes the general purpose knob to *adjust* some function, such as the position of measurement cursors on screen, or the setting for a channel's fine gain.

GUI

The user interface also makes use of a GUI, or Graphical User Interface, to make setting functions and interpreting the display more intuitive. Some menus and status are displayed using iconic representations of function settings such as those shown here for full, 100 MHz, and 20 MHz bandwidth. Such icons allow you to more readily determine status or the available settings.

Signal Acquisition System

The signal acquisition system provides four vertical channels with calibrated vertical scale factors from 1 mV to 10 V per division. All four channels can be acquired simultaneously.

Each of the four channels can be displayed, vertically positioned, and offset, can have their bandwidth limited (to either 100 MHz or 20 MHz) and their vertical coupling specified. Fine gain can also be adjusted.

Besides the four channels, up to three math waveforms and four reference waveforms are available for display. (A math waveform results when you specify dual waveform operations, such as add, on any two channels; a reference waveform results when you save a live waveform in a reference memory.)

Horizontal System

There are three horizontal display modes: main only, main intensified, and delayed only. You can select among various horizontal record length settings (see Table A-7).

Table A-7: Record Length vs Divisions per Record

Record Length[1, 2]	Divisions per Record (50 Points/Division)
30,000	600 divs
15,000	300 divs
5,000	100 divs
2,500	50 divs
1,000	20 divs
500	10 divs

[1]The 15,000 and 30,000 point record lengths are available only with Option 1M.

[2]The maximum record length of 30,000 points for oscilloscopes equipped with Option 1M reduces to 15,000 points when operating in Hi Res or Average acquisition mode.

Both the delayed only display and the intensified zone on the main intensified display can be delayed by time with respect to the main trigger. Both can be set to display immediately after the delay (delayed runs after main mode); the delayed display can also be set to display at the first valid trigger after the delay (delayed triggerable mode).

The delayed display (or the intensified zone) can also be delayed by a selected number of events. In such a case, the events source is the delayed trigger source. For any events signal, the delayed-trigger system conditions the signal by determining the source, coupling, etc., of that signal.

Trigger System

The triggering system comprises a complete set of features for triggering the signal-acquisition system. In edge trigger mode, triggering is configurable for source, slope, coupling, mode (auto or normal), and for holdoff.

Oscilloscopes ordered with Option 5 also have the video trigger mode. This trigger mode will allow triggering on NTSC-standard, PAL-standard, SECAM-standard, or custom video waveforms. Triggering can be configured for interlaced or non-interlaced scanning, different scan rates, field selection, line selection, and for delay by line or time.

You can choose where the trigger point is located within the acquired waveform record by selecting the amount of pretrigger data displayed. Presets of 10%, 50%, and 90% of pretrigger data can be selected in the horizontal menu, or the General Purpose knob can be assigned to set pretrigger data to any value within the limits of trigger position resolution.

Acquisition Control

Depending on your measurement requirements, you can specify the mode and manner in which signals are acquired and processed:

- You can select equivalent-time sampling on repetitive signals or interpolation of points sampled on non-repetitive signals. Both can increase the apparent sample rate on the waveform when maximum real-time rates are reached.
- Peak-detect, high-resolution, sample, envelope, and average modes can be used to acquire signals.
- The acquisition can be set to stop after a single acquisition (or sequence of acquisitions if acquiring in average or envelope modes).

On-Board User Assistance

Two features that help you set up this digitizing oscilloscope to make your measurements are help and autoset.

Help

Help displays operational information about any front-panel control. When help mode is in effect, manipulating any front-panel control causes the digitizing oscilloscope to display information about that control. When help is first invoked, an introduction to help is displayed on screen.

Autoset

Autoset automatically sets up the digitizing oscilloscope for a viewable display based on the input signal.

Measurement Assistance

Once you have set up to make your measurements, the features cursor and measure can help you quickly make those measurements.

Cursor

Two types of cursors are provided for making parametric measurements on the displayed waveforms. Voltage can be measured between the positions of H Bar (horizontal) cursors, and time can be measured between V Bar (vertical) cursors. These are delta measurements; that is, measurements based on the difference between two cursors.

Both V Bar and H Bar cursors can also be used to make absolute measurements—measurements relative to a defined level or event. In the case of the H Bars, either cursor can be selected to read out its voltage with respect to the ground reference level of any channel; in the case of the V Bars, its time with respect to the trigger point (event) of the acquisition.

For time measurements, units can be either seconds or Hertz (for 1/time).

Measure

Measure can automatically extract parameters from the signal input to the digitizing oscilloscope. Any four out of the more than 20 parameters available can be displayed to the screen. The displayed parameters are extracted continuously and the results updated on-screen as the digitizing oscilloscope continues to acquire waveforms.

Digital Signal Processing (DSP)

An important component of the multiprocessor architecture of this digitizing oscilloscope is Tektronix's proprietary digital signal processor, the DSP. This dedicated processor supports advanced analysis of your waveforms when doing such compute-intensive tasks as interpolation, waveform math, and signal averaging. It also teams with a custom display system to deliver specialized display modes (see *Display*, later in this description).

Storage and I/O

Acquired waveforms can be saved in any of four nonvolatile REF (reference) memories. Any or all of the saved waveforms can be displayed for comparison with the waveforms being currently acquired.

The source and destination of waveforms to be saved can be chosen. Assignment can be made to save any of the four channels to any REF memory or to move a stored reference from one REF memory to another. Reference waveforms can also be written into a REF memory location via the GPIB interface.

The digitizing oscilloscope is fully controllable and capable of sending and receiving waveforms over the GPIB interface (IEEE Std 488.1-1987/IEEE Std 488.2-1987 standard). This feature makes the instrument ideal for making automated measurements in a production or research and development environment that calls for repetitive data taking. Self-compensation and self-diagnostic features built into the digitizing oscilloscope to aid in fault detection and servicing are also accessible using commands sent from a GPIB controller.

Another standard feature is hardcopy. This feature allows you to output waveforms and other on-screen information to a variety of graphic printers and plotters from the digitizing oscilloscope front panel, providing hard copies without requiring you to put the digitizing oscilloscope into a system-controller environment. The hard copies obtained are WYSIWYG (What-You-See-Is-What-You-Get), based on what is displayed at the time hardcopy is invoked.

A VGA-compatible video output, available at the rear panel, is also standard with the TDS 400 digitizing oscilloscope.

Display

The TDS 400 Digitizing Oscilloscopes offer flexible display options. You can customize the following attributes of your display:

- Intensity: waveforms, readouts, graticule, etc.
- Style of waveform display(s): vectors or dots, intensified or non-intensified samples, and infinite or variable persistence
- Display format: XY or YT and graticule type

Zoom

This digitizing oscilloscope also provides an easy way to focus in on those waveform features you wish to examine up close. By invoking zoom, you can magnify the waveform parameter using the vertical and horizontal controls to expand (or contract) and position it for viewing.

Nominal Traits

This subsection contains a collection of tables that list the various *nominal traits* that describe the TDS 400 Digitizing Oscilloscopes. Included are electrical and mechanical traits.

Nominal traits are described using simple statements of fact such as "Four, all identical" for the trait "Input Channels, Number of," rather than in terms of limits that are performance requirements.

In the tables that follow, traits that differ according to model or only apply to one of the two models are labeled using the appropriate model number, TDS 420 or TDS 460.

Table A-8: Nominal Traits—Signal Acquisition System

Name	Description		
Bandwidth Selections	TDS 420: 20 MHz, 100 MHz, and FULL (150 MHz) TDS 460: 20 MHz, 100 MHz, and FULL (350 MHz)		
Digitizers, Number of	Four, all identical		
Digitized Bits, Number of	8 bits[1]		
Input Channels, Number of	Four, all identical, called CH 1–CH 4		
Input Coupling	DC, AC, or GND		
Input Resistance Selections	1 MΩ or 50 Ω		
Ranges, Offset, All Channels	**Volts/Div Setting**	**Offset Range**	
	1 mV/div–99.5 mV/div	±1 V	
	100 mV/div–995 mV/div	±10 V	
	1 V/div–10 V/div	±100 V	
Range, Position	±5 divisions		
Range, Sensitivity	1 mV/div to 10 V/div[2]		
Rise Time[3]	**Volts/Div Setting**	**Rise Time**	
		TDS 420	**TDS 460**
	5 mV/div–10 V/div	2.3 ns	1.0 ns
	2 mV/div–4.98 mV/div	3.2 ns	1.4 ns
	1 mV/div–1.99 mV/div	3.9 ns	3.5 ns

[1]Displayed vertically with 25 digitization levels (DLs) per division and 10.24 divisions dynamic range with zoom off. A DL is the smallest voltage level change that can be resolved by the 8-bit A-D Converter, with the input scaled to the volts/division setting of the channel used. Expressed as a voltage, a DL is equal to 1/25 of a division times the volts/division setting.

[2]The sensitivity ranges from 1 mV/div to 10 V/div in a 1–2–5 sequence of coarse settings. Between consecutive coarse settings, the sensitivity can be finely adjusted with a resolution of 1% of the more sensitive setting. For example, between 50 mV/div and 100 mV/div, the volts/division can be set with 0.5 mV resolution.

[3]Rise time is defined by the following formula:

$$\text{Rise Time (ns)} = \frac{350}{\text{BW (MHz)}}$$

Table A-9: Nominal Traits—Time Base System

Name	Description
Range, Sample-Rate[1,3]	2.5 Samples/s to 100 MSamples/s
Range, Equivalent Time or Interpolated Waveform Rate[2,3]	200 MSamples/s to 50 GSamples/s (5 ns/Sample to 20 ps/Sample)
Range, Seconds/Division	1 ns/div to 20 s/div
Range, Time Base Delay Time	0 to 20 seconds
Reference Frequency,Time Base	100 MHz
Record Length Selection	500 points, 1,000 points, 2,500 points, 5,000 points. Record lengths of 15,000 points and 30,000 points are available with Option 1M.[4]

[1]The range of real-time rates, expressed in samples/second, at which a digitizer samples signals at its inputs and stores the samples in memory to produce a record of time-sequential samples

[2]The range of waveform rates for equivalent time or interpolated waveform records.

[3]The Waveform Rate (WR) is the equivalent sample rate of a waveform record. For a waveform record acquired by real-time sampling of a single acquisition, the waveform rate is the same as the real-time sample rate; for a waveform created by interpolation of real-time samples from a single acquisition or by equivalent-time sampling of multiple acquisitions, the waveform rate is faster than the real time sample rate. For all three cases, the waveform rate is 1/(Waveform Interval) for the waveform record, where the waveform interval (WI) is the time between the samples in the waveform record.

[4]The maximum record length of 30,000 points available with Option 1M is selectable with all acquisition modes except Hi Res and Average. In Hi Res and Average, the maximum record length is 15,000 points.

Table A-10: Nominal Traits—Triggering System

Name	Description	
Range, Events Delay	1 to 9,999,999	
Ranges,Trigger Level or Threshold	**Source**	**Range**
	Any Channel	±12 divisions from center of screen
	Line	±400 Volts
Video Mode (Option 05 Equipped Instruments Only)	Line Rate Class: Four classes are provided as follows. ■ NTSC, which provides a default line rate compatible with the NTSC standard (525/60) ■ PAL, which provides a default line rate compatible with the PAL standard (625/50) ■ SECAM, which provides a default line rate compatible with the SECAM standard ■ Custom, which provides user selectable line rate ranges (see "Custom Line Rate Ranges" below) Custom Line Rate Ranges: 15 kHz–20 kHz, 20 kHz–25 kHz, and 25 kHz–35 kHz, and 35 kHz–64 kHz Holdoff: Automatically adjusts to 50 ms (nominal) for NTSC class; to 140 ms (nominal) for PAL class Triggerable on Field Selections: Odd, Even, or Both Delayed Acquisition: Settable for delay by line number or runs after time delay	

Table A-11: Nominal Traits—Display System

Name	Description
Video Display Resolution	640 pixels horizontally by 480 pixels vertically in a display area of 5.04 inches horizontally by 3.78 inches vertically
Waveform Display Graticule	A single graticule 401 × 501 pixels (8 × 10 divisions, with divisions that are 1 cm by 1 cm)
Waveform Display Grey Scale	Sixteen levels in infinite-persistence and variable-persistence display styles

Table A-12: Nominal Traits—Data Storage

Name	Description
Capacity, Nonvolatile Waveform Memory	Standard Instrument: Total capacity is 20,000 points (four waveforms acquired with maximum record lengths of 5,000 points each). Option 1M Equipped Instrument: Total capacity is 60,000 points (two to four waveforms acquired with any combination of record lengths that add up to 60,000 points). For available record lengths, see "Record Length Selection" on page A-16 of this section.
Capacity, Nonvolatile Setup Memory	Ten setups
Retention Time, Nonvolatile Memories	Internal batteries, installed at time of manufacture, have a life of ≥5 years when operated and/or stored at an ambient temperature from 0°C to 50°C. Retention time of the nonvolatile memories is equal to the remaining life of the batteries.
Batteries[1] Required	Two lithium poly-carbon monofluoride. Both are type BR2/3A, UL listed. Both are rated at 3.0 volt, 1.2 amp-hour.

[1]**Batteries are not accessible from the outside of the instrument; therefore, they can only be replaced by a service technician.**

Table A-13: Nominal Traits—GPIB Interface, Video Output, and Power Fuse

Name	Description
Interface, GPIB	GPIB interface complies with IEEE Std 488.1-1987 and IEEE Std 488.2-1987.
Output, Video	Provides a video signal, non-interlaced, with levels that comply with ANSI RS343A. Output is through a rear-panel DB9 connector.
Fuse Rating	Either of two fuses[1] may be used: a .25″ × 1.25″ (UL 198.6, 3AG): 5 A FAST, 250 V, or a 5 mm × 20 mm, (IEC 127): 5 A (T), 250 V.

[1]**Each fuse type requires its own fuse cap.**

Table A-14: Nominal Traits—Mechanical

Name	Description
Cooling Method	Forced-air circulation with no air filter.
Construction Material	Chassis parts constructed of aluminum alloy; front panel constructed of plastic laminate; circuit boards constructed of glass-laminate. Cabinet is aluminum with Tektronix Blue textured finish.
Finish Type	Tektronix Blue textured finish on aluminum cabinet.

Table A-14: Nominal Traits—Mechanical (Cont.)

Name	Description
Weight	Standard digitizing oscilloscope 8.6 kg (19.0 lbs), oscilloscope only. 10.2 kg (22.5 lbs), with front cover, accessories, and accessories pouch installed. 14.5 kg (32.0 lbs), when packaged for domestic shipment. Rackmount digitizing oscilloscope 8.2 kg (18.0 lbs) plus the weight of rackmount parts, for the rackmounted digitizing oscilloscope (Option 1R). 16.3 kg (36.0 lbs), when the rackmounted digitizing oscilloscope is packaged for domestic shipment. Rackmount conversion kit 4.5 kg (10.0 lbs), parts only; 7.9 kg (17.5 lbs), parts plus package for domestic shipping.
Overall Dimensions	Standard digitizing oscilloscope Height 191 mm (7.5 in), when feet and accessories pouch are installed. 165 mm (6.5 in), without the accessories pouch installed. Width 362 mm (14.25 in), with handle. Depth 471 mm (18.55 in), oscilloscope only; 490 mm (19.28 in), with optional front cover installed; 564 mm (22.2 in) with handle fully extended. Rackmount digitizing oscilloscope Height 178 mm (7.0 in). Width 483 mm (19.0 in). Depth 472 mm (18.6 in), without front-panel handles; 517 mm (20.35 in) with front-panel handles installed.

Warranted Characteristics

This subsection lists the various *warranted characteristics* that describe the TDS 400 Digitizing Oscilloscopes. (Characteristics that differ according to model number or only apply to one of the two models are labeled using the appropriate model number, TDS 420 or TDS 460.) Included are electrical and environmental characteristics.

Warranted characteristics are described in terms of quantifiable performance limits which are warranted. This subsection lists only warranted characteristics. A list of *typical characteristics* starts on page A-25.

NOTE

In these tables, those warranted characteristics that are checked in the procedure Performance Verification, *found in Section 4, appear in* ***boldface type*** *under the column* **Name**.

Performance Conditions

The electrical characteristics found in these tables of warranted characteristics apply when the scope has been adjusted at an ambient temperature between +20°C and +30°C, has had a warm-up period of at least 20 minutes, and is operating at an ambient temperature between 0°C and +50°C (unless otherwise noted).

Table A-15: Warranted Characteristics—Signal Acquisition System

Name	Description	
Accuracy, DC Voltage Measurement, Averaged	**Measurement Type**	**DC Accuracy**
	Average of ≥16 waveforms	±(1.5% × |(reading − Net Offset[1])| + Offset Accuracy + 0.06 div)
	Delta volts between any two averages of ≥16 waveforms[2]	±(1.5% × |reading| + 0.1 div + 0.3 mV)
Accuracy, DC Gain [3]	±1.5%	
Accuracy, Offset	**Volts/Div Setting**	**Offset Accuracy**
	1 mV/div – 9.95 mV/div	±(0.4% × |Net Offset[1]| + 0.9 mV + 0.1 div)
	10 mV/div – 99.5 mV/div	±(0.4% × |Net Offset[1]| + 1.5 mV + 0.1 div)
	100 mV/div – 995 mV/div	±(0.4% × |Net Offset[1]| + 15 mV + 0.1 div)
	1 V/div – 10 V/div	±(0.4% × |Net Offset[1]| + 150 mV + 0.1 div)

[1]Net Offset = Offset – (Position x Volts/Div). Net Offset is the voltage level at the center of the A-D converter's dynamic range. Offset Accuracy is the accuracy of this voltage level.

[2]The samples must be acquired under the same setup and ambient conditions.

[3]DC Gain Accuracy is confirmed in the Performance Verification Procedure found in Appendix C by passing the checks for Offset Accuracy and DC Voltage Measurement Accuracy (Averaged).

Table A-15: Warranted Characteristics – Signal Acquisition System (Cont.)

Name	Description		
Accuracy, Position[4]	±(1.5% × (Position × Volts/div) + Offset Accuracy + 0.04 div)		
Analog Bandwidth, DC-50 Ω Coupled and DC-1 MΩ Coupled with Standard-accessory Probe Attached	**Volts/Div**	**Bandwidth[5]**	
		TDS 420	**TDS 460**
	5 mV/div – 10 V/div	DC – 150 MHz	DC – 350 MHz
	2 mV/div – 4.98 mV/div	DC – 110 MHz	DC – 250 MHz
	1 mV/div – 1.99 mV/div	DC – 90 MHz	DC – 100 MHz
Cross Talk (Channel Isolation)	TDS 460:		
	Volt/Div	**Isolation**	
	≥500 mV/div	≥50:1 at 50 MHz for any two channels having equal volts/division settings	
	≤9.95 mV/div	≥50:1 at 50 MHz for any two channels having equal volts/division settings	
	10 mV/div – 500 mV/div	≥100:1 at 100 MHz and ≥ 30:1 at full rated bandwidth for any two channels having equal volts/division settings	
Delay Between Channels, Full Bandwidth, Equivalent Time	≤200 ps between CH 1 and CH 2 and between CH 3 and CH 4 when both channels have equal volts/division and coupling settings ≤450 ps for any other combination of two channels with equal volts/division and coupling settings		
Input Impedance, DC-1 MΩ Coupled	1 MΩ ±0.5% in parallel with 15 pF ±2.0 pF. Matched to within ±1% for resistance and ±1.0 pF for capacitance		
Input Impedance, DC-50 Ω Coupled	TDS 420: 50 Ω ±1% with VSWR ≤1.2:1 from DC – 150 MHz TDS 460: 50 Ω ±1% with VSWR ≤1.6:1 from DC – 350 MHz		
Input Voltage, Maximum, DC-1 MΩ, AC-1 MΩ, or GND Coupled	**Volt/Div**	**Rating**	
	0.1 V/div – 10 V/div	±400 V (DC + peak AC); derate at 20 dB/decade above 10 MHz until the minimum rating of ±5 V (DC + peak AC) is reached	
	1 mV/div – 9.99 mV/div	±400 V (DC + peak AC); derate at 20 dB/decade above 10 kHz until the minimum rating of ±5 V (DC + peak AC) is reached	

[4]Position Accuracy is confirmed in the Performance Verification Procedure found in Appendix C by passing the checks for Offset Accuracy and DC Voltage Measurement Accuracy (Averaged).

[5]The limits given are for the ambient temperature range of 0°C to +30°C. Reduce the upper bandwidth frequencies by 2.5 MHz for each °C above +30°C.

Table A-15: Warranted Characteristics—Signal Acquisition System (Cont.)

Name	Description
Input Voltage, Maximum, DC-50 Ω or AC-50 Ω Coupled	5 V rms, with peaks less than or equal to ±30 V
Lower Frequency Limit, AC Coupled	≤10 Hz when AC–1 MΩ coupled; ≤200 kHz when AC-50 Ω coupled[6]

[6]The AC Coupled Lower Frequency Limits are reduced by a factor of 10 when 10X, passive probes are used.

Table A-16: Warranted Characteristics—Time Base System

Name	Description
Accuracy, Long Term Sample Rate and Delay Time	±150 ppm over any ≥1 ms interval
Accuracy, Absolute Time and Delay Time Measurements[1, 2]	For single-shot acquisitions using sample or high-resolution acquisition modes and a bandwidth limit setting of 100 MHz: ±(1 WI + 150 ppm of |Reading| + 450 ps) For single-shot acquisitions using sample or high-resolution acquisition modes and a bandwidth limit setting of 20 MHz: ±(1 WI + 150 ppm of |Reading| + 1.3 ns) For repetitive acquisitions using average acquisition mode with ≥8 averages and a bandwidth limit setting of FULL: ±(1 WI + 150 ppm of |Reading| + 200 ps)
Accuracy, Delta Time Measurement[1, 2]	For single-shot acquisitions using sample or high-resolution acquisition modes and a bandwidth limit setting of 100 MHz: ±(1 WI + 150 ppm of |Reading| + 650 ps) For repetitive acquisitions using average acquisition mode with ≥8 averages and a bandwidth limit setting of FULL: ±(1 WI + 150 ppm of |Reading| + 300 ps)

[1]For input signals ≥ 5 divisions in amplitude and a slew rate of ≥ 2.0 divisions/ns at the delta time measurement points. Signal must have been acquired at a volts/division setting ≥ 5 mV/division.

[2]The WI (waveform interval) is the time between the samples in the waveform record. Also, see the footnotes for *Sample Rate Range* and *Equivalent Time or Interpolated Waveform Rates* in Table A-9 on page A-16.

Table A-17: Warranted Characteristics—Triggering System

Name	Description
Accuracy, Trigger Level or Threshold, DC Coupled	±(2% of |Setting − Net Offset[1]| + 0.2 div × volts/div setting + Offset Accuracy) for any channel as trigger source
Sensitivity, Edge-Type Trigger, DC Coupled[2]	TDS 420: 0.35 division from DC to 50 MHz, increasing to 1 division at 350 MHz for any channel as trigger source TDS 460: 0.35 division from DC to 50 MHz, increasing to 1 division at 500 MHz for any channel as trigger source
Sensitivity, Video-Type, TV Field and TV Line[2]	0.6 division of video sync signal
Pulse Width, minimum, Events-Delay	5 ns
Auxiliary Trigger Input	Connector: BNC at rear panel Input Voltage (maximum): −5 VDC to +10 VDC Duty Cycle (minimum required): 20% Input Load: equivalent to three TTL gate loads
Auxiliary Trigger, Maximum Input Frequency	10 MHz

[1]Net Offset = Offset − (Position x Volts/Div). Net Offset is the voltage level at the center of the A-D converter's dynamic range. Offset Accuracy is the accuracy of this voltage level.

[2]The minimum sensitivity for obtaining a stable trigger. A stable trigger results in a uniform, regular display triggered on the selected slope. The trigger point must not switch between opposite slopes on the waveform, and the display must not "roll" across the screen on successive acquisitions. The TRIG'D LED stays constantly lighted when the SEC/DIV setting is 2 ms or faster but may flash when the SEC/DIV setting is 10 ms or slower.

Table A-18: Warranted Characteristics—Probe Compensator Output

Name	Description	
Output Voltage and Frequency, Probe Compensator	**Characteristic**	**Limits**
	Voltage	0.5 V (base-top) ±5% into a 1 MΩ load
	Frequency	1 kHz ±5%

Table A-19: Power Requirements

Name	Description
Source Voltage and Frequency	90 to 132 VAC rms, continuous range, for 48 Hz through 62 Hz 100 to 132 VAC rms, continuous range, for 48 Hz through 440 Hz 180 to 250 VAC rms, continuous range, for 48 Hz through 440 Hz
Power Consumption	≤240 Watts (225 VA)

Table A-20: Warranted Characteristics—Environmental, Safety, and Reliability

Name	Description
Atmospherics	Temperature: 0°C to +50°C, operating; –40°C to +75°C, non-operating Relative humidity: 0 to 95%, at or below +40°C; 0 to 75%, +41°C to +50°C Altitude: To 15,000 ft. (4570 m), operating; to 40,000 ft. (12190 m), non-operating
Dynamics	Random vibration: 0.31 g rms, from 5 to 500 Hz, 10 minutes each axis, operating; 2.46 g rms, from 5 to 500 Hz, 10 minutes each axis, non-operating
Emissions[1, 2]	Meets or exceeds the requirements of the following standards: VDE 0871, Category B FCC Rules and Regulations, Part 15, Subpart J, Class A
User-Misuse Simulation	Electrostatic Discharge Susceptibility: Up to 8 kV with no change to settings or impairment of normal operation; up to 15 kV with no damage that prevents recovery of normal operation

[1]To maintain emission requirements when connecting to the IEEE 488 GPIB interface of this oscilloscope, use only a high-quality, double-shielded (braid and foil) GPIB cable. The cable shield must have low impedance connections to both connector housings. Acceptable cables are Tektronix part numbers 012-0991-00, -01, -02, and -03.

[2]To maintain emission requirements when connecting to the VGA-compatible video output of this oscilloscope, use only a high-quality double-shielded (braid and foil) video cable with ferrite cores at either end. The cable shield must have low impedance connections to both connector housings. An acceptable cable is NEC® part number 73893013. (Use an appropriate adapter when other than a 9-pin monitor connection is needed.)

Typical Characteristics

This subsection contains tables that lists the various *typical characteristics* that describe the TDS 400 Digitizing Oscilloscopes.

Typical characteristics are described in terms of typical or average performance. Typical characteristics are not warranted.

This subsection lists only typical characteristics. A list of warranted characteristics starts on page A-20.

Table A-21: Typical Characteristics—Signal Acquisition System

Name	Description				
Accuracy, DC Voltage Measurement, Not Averaged	**Measurement Type**	**DC Accuracy**			
	Any Sample	±(1.5% × (|reading – Net Offset[1]|) + Offset Accuracy + 0.13 div + 0.6 mV)			
	Delta Volts between any two samples[2]	±(1.5% × |reading| + 0.26 div + 1.2 mV)			
Frequency Limit, Upper, 100 MHz Bandwidth Limited	100 MHz				
Frequency Limit, Upper, 20 MHz Bandwidth Limited	20 MHz				
Nonlinearity	<1 DL, differential; ≤ 1 DL, integral, independently based[3]				
Step Response Settling Error	**Volts/Div Setting**	**Step Amplitude**	**Settling Error (%)[4]**		
			20 ns	**500 ns**	**20 ms**
	1 mV/div–99.5 mV/div	≤2 V	≤0.5	≤0.2	≤0.1
	100 mV/div–995 mV/div	≤20 V	≤2.0	≤0.5	≤0.2
	1 V/div–10 V/div	≤200 V	≤2.0	≤0.5	≤0.2

[1]Net Offset = Offset – (Position x Volts/Div). Net Offset is the voltage level at the center of the A-D converter's dynamic range. Offset Accuracy is the accuracy of this voltage level.

[2]The samples must be acquired under the same setup and ambient conditions.

[3]A DL (digitization level) is the smallest voltage level change that can be resolved by the 8-bit A-D Converter, with the input scaled to the volts/division setting of the channel used. Expressed as a voltage, a DL is equal to 1/25 of a division times the volts/division setting.

[4]The values given are the maximum absolute difference between the value at the end of a specified time interval after the mid-level crossing of the step, and the value one second after the mid-level crossing of the step, expressed as a percentage of the step amplitude.

Table A-22: Typical Characteristics—Time Base System

Name	Description
Aperture Uncertainty	For real-time or interpolated records having duration ≤1 minute: ≤(50 ps + 0.03 ppm × Record Duration) RMS For equivalent time records: ≤(50 ps + 0.06 ppm × WI[1]) RMS
Fixed Error in Sample Time	≤50 ps

[1]The WI (waveform interval) is the time between the samples in the waveform record. Also, see the footnotes for *Sample Rate Range* and *Equivalent Time or Interpolated Waveform Rates* in Table A-9 on page A-16.

Table A-23: Typical Characteristics—Triggering System

Name	Description		
Error, Trigger Position, Edge Triggering	**Acquire Mode**	**Trigger-Position Error[1,2]**	
	Sample, Hi-Res, Average	±(1 WI + 1 ns)	
	Peak Detect, Envelope	±(2 WI + 1 ns)	
Holdoff, Variable, Main Trigger	**Main Horizontal Scale**	**Minimum Holdoff**	**Maximum Holdoff**
	≤100 ns/div	1 µs	5 × Min Holdoff
	≥100 ms/div	1 s	5 × Min Holdoff
	Otherwise	10 × sec/div	5 × Min Holdoff
Lowest Frequency for Successful Operation of "Set Level to 50%" Function	20 Hz		
Sensitivity, Edge Trigger, Not DC Coupled[3]	**Trigger Coupling**	**Typical Signal Level for Stable Triggering**	
	AC	Same as DC-coupled limits[4] for frequencies above 60 Hz. Attenuates signals below 60 Hz.	
	Noise Reject	Three and one half times the DC-coupled limits.[4]	
	High Frequency Reject	One and one half times times the DC-coupled limits[4] from DC to 30 kHz. Attenuates signals above 30 kHz.	
	Low Frequency Reject	One and one half times the DC-coupled limits[4] for frequencies above 80 kHz. Attenuates signals below 80 kHz.	
Frequency, Maximum for Events Delay[5]	90 MHz		
Width, Minimum Pulse and Rearm, Events Delay[6]	5 ns		

[1]The trigger position errors are typically less than the values given here. These values are for triggering signals having a slew rate at the trigger point of ±0.5 division/ns.

[2]The waveform interval (WI) is the time between the samples in the waveform record. Also, see the footnote for the characteristics *Sample Rate Range* and *Equivalent Time or Interpolated Waveform Rates* in Table A-9 on page A-16.

[3]The minimum sensitivity for obtaining a stable trigger. A stable trigger results in a uniform, regular display triggered on the selected slope. The trigger point must not switch between opposite slopes on the waveform, and the display must not "roll" across the screen on successive acquisitions. The TRIG'D LED stays constantly lighted when the SEC/DIV setting is 2 ms or faster but may flash when the SEC/DIV setting is 10 ms or slower.

[4]See the characteristic *Sensitivity, Edge-Type Trigger, DC Coupled* in Table A-17, which begins on page A-23.

[5]The maximum frequency for a delaying events input.

[6]The minimum pulse width and rearm width required for recognizing a delaying event.

Table A-24: Typical Characteristics—Data Handling

Name	Description
Time, Data-Retention, Nonvolatile Memory[1,2]	5 Years

[1]The time that reference waveforms, stored setups, and calibration constants are retained when there is no power to the oscilloscope.

[2]Data is maintained by lithium poly-carbon monofluoride batteries.

Appendix C: Performance Verification

Brief Procedures

The *Self Tests* use internal routines to confirm basic functionality and proper adjustment. No test equipment is required to do these test procedures.

The *Functional Tests* utilize the probe-adjust output at the front panel as a test-signal source for further verifying that the oscilloscope functions properly. A standard-accessory probe, included with this oscilloscope, is the only equipment required.

General Instructions

These procedures verify the TDS 400 Digitizing Oscilloscopes.

Besides the *Brief Procedures,* the set of procedures that can be used to verify oscilloscope performance includes the *Performance Tests,* found later in this section. You may not need to perform all of these procedures, depending on what you want to accomplish:

- To rapidly confirm that this oscilloscope functions and was adjusted properly, just do the procedures under *Self Tests*, which begin on page A-32.

  Advantages: These procedures are quick to do, require no external equipment or signal sources, and perform extensive functional and accuracy testing to provide high confidence that the oscilloscope will perform properly. They can be used as a quick check before making a series of important measurements.

- To further check functionality, first do the *Self Tests* just mentioned; then do the procedures under *Functional Tests* that begin on page A-33.

  Advantages: These procedures require minimal additional time to perform, require no additional equipment other than a standard-accessory probe, and more completely test the internal hardware of this oscilloscope. They can be used to quickly determine if the oscilloscope is suitable for putting into service, such as when it is first received.

- If more extensive confirmation of performance is desired, do the *Performance Tests*, beginning on page A-39, after doing the *Functional* and *Self Tests* just referenced.

  Advantages: These procedures add direct checking of warranted specifications. They require more time to perform and suitable test equipment is required. (See *Equipment Required* on page A-39.)

If you are not familiar with operating this oscilloscope, read *General Operating Instructions* in Section 3 of this manual. These instructions will acquaint you with the use of the front-panel controls and the menu system.

Conventions

Throughout these procedures the following conventions apply:

- Each test procedure uses the following general format:

  Title of Test

  Equipment Required

  Prerequisites

  Procedure

- Each procedure consists of as many steps, substeps, and subparts as required to do the test. Steps, substeps, and subparts are sequenced as follows:

1. First Step
   a. First Substep
      - First Subpart
      - Second Subpart
   b. Second Substep
2. Second Step

- In steps and substeps, the lead-in statement in italics instructs you what to do, while the instructions that follow tell you how to do it: in the example step below, *"Initialize the oscilloscope"* by doing "Press save/recall **SETUP**. Now, press the main menu button... ."

  Initialize the oscilloscope: Press save/recall **SETUP**. Now, press the main menu button **Recall Factory Setup**; then the side menu button **OK Confirm Factory Init**.

- Where instructed to use a front-panel button or knob, or select from a main or side menu, or verify a readout or status message, the name of the button or knob appears in boldface type: "press **SHIFT**; then **ACQUIRE MENU**," "press the main menu button **Coupling**," or "verify that the status message is ***Pass***."

The symbol at the left is accompanied by information you must read to do the procedure properly.

- Refer to Figure A-1: "Main menu" refers to the menu that labels the seven menu buttons under the display; "side menu" refers to the menu that labels the five buttons to the right of the display. "Pop-up menu" refers to a menu that pops up the when a main menu button is pressed.

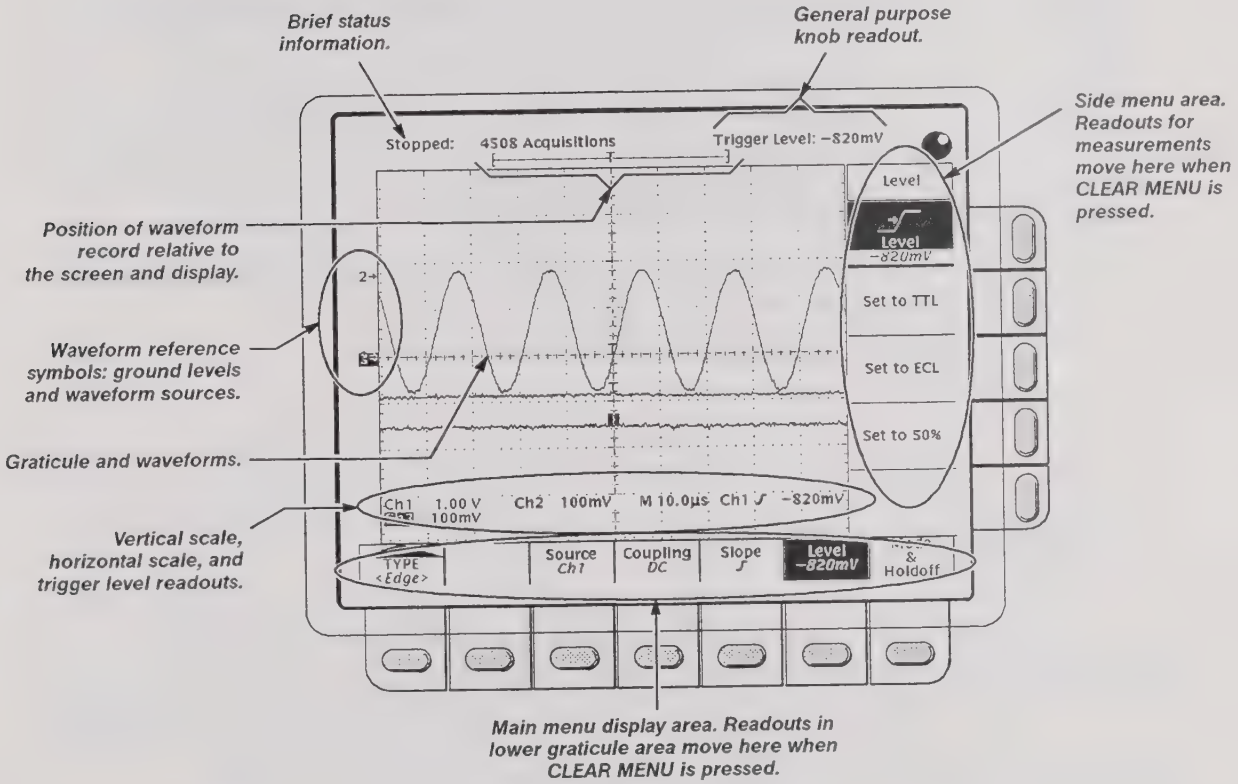

Brief status information.
General purpose knob readout.
Side menu area. Readouts for measurements move here when CLEAR MENU is pressed.
Position of waveform record relative to the screen and display.
Waveform reference symbols: ground levels and waveform sources.
Graticule and waveforms.
Vertical scale, horizontal scale, and trigger level readouts.
Main menu display area. Readouts in lower graticule area move here when CLEAR MENU is pressed.
Stopped: 4508 Acquisitions
Trigger Level: -820mV
Level
Level
-820mV
Set to TTL
Set to ECL
Set to 50%
Ch1 1.00 V 100mV
Ch2 100mV
M 10.0µs Ch1 ƒ -820mV
TYPE <Edge>
Source Ch1
Coupling DC
Slope
Level -820mV
Holdoff

Figure A-1: Map of Display Functions

- Where instructed to use a front-panel button or knob, or select from a main or side menu, or verify a readout or status message, the name of the button or knob appears in boldface type: "press **SHIFT**; then **ACQUIRE MENU**," "press the main menu button **Coupling**," or "verify that the status message is ***Pass***."

- In steps and substeps, the lead in statement in italics instructs you what to do, while the instructions that follow tell you how to do it: in the example step below, *"Initialize the instrument"* by doing "Press save/recall **SETUP**. Now, press the main menu button... ."

  Initialize the instrument: Press **SAVE/RECALL SETUP**. Now, press the main menu button **Recall Factory Setup**; then the side menu button **OK Confirm Factory Init**.

Self-Tests

This procedure uses internal routines to verify that this oscilloscope functions and passes its internal self tests and signal path compensations. It also confirms that the oscilloscope was adjusted properly at the time it was last adjusted. No test equipment or hookups are required.

Verify Internal Adjustment, Self Compensation, and Diagnostics

Equipment Required: None.

Prerequisites: Power up the digitizing oscilloscope and allow a 20 minute warm-up before doing this procedure.

Procedure:

1. *Verify that internal diagnostics pass:* Do the following substeps to verify passing of internal diagnostics.
   a. *Display the System diagnostics menu:*
      - Press **SHIFT**; then press **UTILITY**.
      - Repeatedly press the main menu button **System** until **Diag/Err** is highlighted in the menu that pops up.
      - Repeatedly press the main menu button **Area** until **All** is highlighted in the menu that pops up.
   b. *Run the System Diagnostics:* Press the main menu button **Execute**; then press the side menu button **OK Confirm Run Test**.
   c. *Wait:* The internal diagnostics do an exhaustive verification of proper oscilloscope function. This verification will take up to a minute. While it progresses, a variety of test patterns will flash on screen. When finished, the resulting status will appear on the screen.
   d. *Confirm no failures are found:* Verify that no failures are found and reported on-screen.
   e. *Confirm the four adjustment sections have passed status:*
      - Press **SHIFT**; then press **UTILITY**.
      - Press the main menu button **System** until **Cal** is highlighted in the pop-up menu.
      - Verify that the word ***Pass*** appears in the main menu under the following menu labels: **Voltage Reference**, **High Frequency Response**, **Low Frequency Response**, and **Trigger Skew**. (See Figure A-2.)

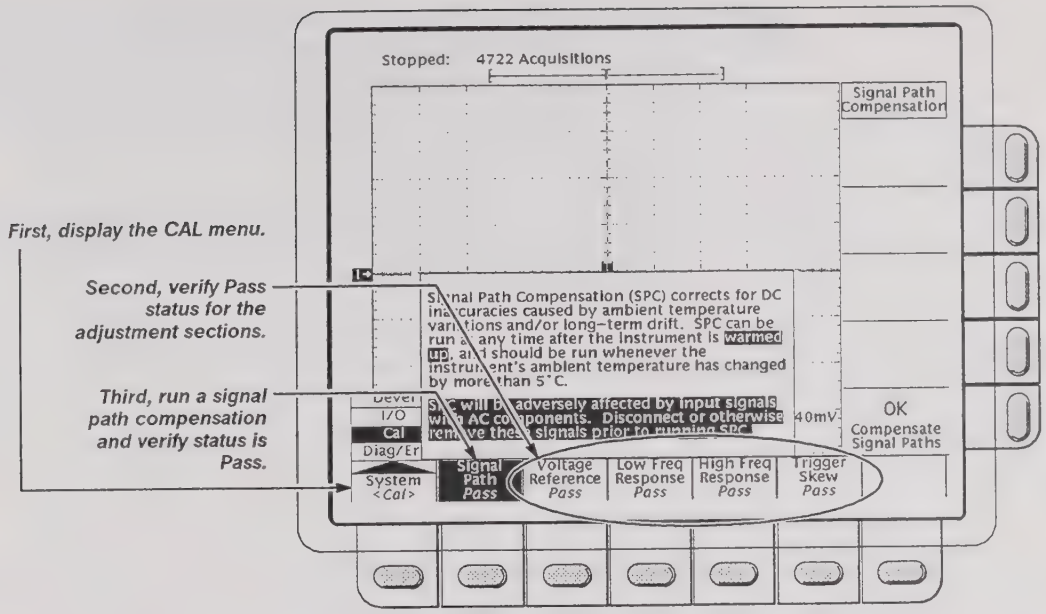

First, display the CAL menu.
Second, verify Pass status for the adjustment sections.
Third, run a signal path compensation and verify status is Pass.
Stopped: 4722 Acquisitions
Signal Path Compensation
Signal Path Compensation (SPC) corrects for DC inaccuracies caused by ambient temperature variations and/or long-term drift. SPC can be run at any time after the instrument is warmed up, and should be run whenever the instrument's ambient temperature has changed by more than 5°C.
I/O
Cal
Diag/Er
40mV
OK Compensate Signal Paths
System <Cal>
Signal Path Pass
Voltage Reference Pass
Low Freq Response Pass
High Freq Response Pass
Trigger Skew Pass

Figure A-2: Verifying Adjustments and Signal-Path Compensation

f. *Run the signal-path compensation:* Press the main menu button **Signal Path**; then press the side menu button **OK Compensate Signal Paths**.

g. *Wait:* Signal-path compensation runs in one to three minutes. While it progresses, a "clock" icon (shown at left) is displayed on-screen. When compensation completes, the status message will be updated to *Pass* or *Fail* in the main menu (see step h).

h. *Confirm signal-path compensation returns passed status:* Verify the word ***Pass*** appears under **Signal Path** in the main menu. (See Figure A-2.)

2. *Return to regular service:* Press **CLEAR MENU** to exit the system menus.

Functional Tests

The purpose of these procedures is to confirm that this oscilloscope functions properly. The only equipment required is one of the standard-accessory probes.

These procedures verify functions; that is, they verify that oscilloscope features *operate*. They do *not* verify that they operate within limits.

Therefore, when the instructions in the functional tests that follow call for you to verify that a signal appears on-screen "that is about five divisions in amplitude" or "has a period of about six horizontal divisions," etc., do *NOT* interpret the quantities given as limits. Operation within limits is checked in *Performance Tests*, which begin on page A-39.

DO NOT make changes to the front-panel settings that are not called out in the procedures. Each verification procedure will require you to set the oscilloscope to certain default settings before verifying functions. If you make changes to these settings, other than those called out in the procedure, you may obtain invalid results. In this case, just redo the procedure from step 1.

When you are instructed to press a menu button, the button may already be selected (its label will be highlighted). If this is the case, it is not necessary to press the button.

Verify All Input Channels

Equipment Required: One P6138 probe.

Prerequisites: None.

Procedure:

1. *Install the test hookup and preset the oscilloscope controls:*

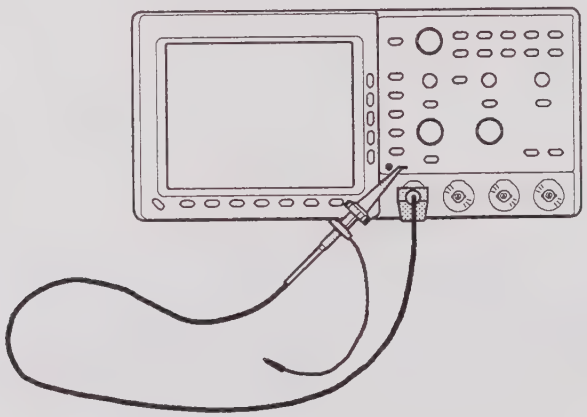


Figure A-3: Universal Test Hookup for Functional Tests

a. *Hook up the signal source:* Install the probe on **CH 1**. Connect the probe tip to **PROBE ADJ SIGNAL** on the front panel; leave the probe ground unconnected.

b. *Initialize the oscilloscope:*

- Press save/recall **SETUP**.
- Press the main menu button **Recall Factory Setup**.
- Press the side menu button **OK Confirm Factory Init**.

2. *Verify that all input channels operate:* Do the following substeps—test CH 1 first, *skipping substep a since CH 1 is already set up for verification from step 1.*

a. *Select an unverified channel:*

- Press **WAVEFORM OFF** to remove from display the channel just verified.
- Press the front-panel button that corresponds to the channel you are to verify.
- Move the probe to the channel you selected.

b. *Set up the selected channel:*

- Press **AUTOSET** to obtain a viewable, triggered display in the selected channel.
- Set the vertical **SCALE** to 100 mV. Use the vertical **POSITION** knob to center the waveform vertically on screen.
- Set the horizontal **SCALE** to 200 µs.
- Press **TRIGGER MENU**.
- Press the main menu button **Coupling**; then press the side menu-button **HF Rej**.

c. *Verify that the channel is operational:* Confirm that the following statements are true.

- The vertical scale readout for the channel under test shows a setting of 100 mV, and a square-wave probe-compensation signal about five divisions in amplitude is on-screen. (See Figure A-1 on page A-31 to locate the readout.)
- The vertical **POSITION** knob moves the signal up and down the screen when rotated.
- Turning the vertical **SCALE** knob counterclockwise decreases the amplitude of the waveform on-screen, turning the knob clockwise increases the amplitude, and returning the knob to 100 mV returns the amplitude to about five divisions.

d. *Verify that the channel acquires in all acquisition modes:* Press **SHIFT**; then press **ACQUIRE MENU**. Use the side menu to select, in turn, each of the five hardware acquire modes and confirm that the following statements are true. Refer to the icons at the left of each statement as you confirm those statements.

- **Sample** mode displays an actively acquiring waveform on-screen. (Note that there is noise present on the peaks of the square wave.)

- **Peak Detect** mode displays an actively acquiring waveform on-screen with the noise present in Sample mode "peak detected."

- **Hi Res** mode displays an actively acquiring waveform on-screen with the noise that was present in Sample mode reduced.

- **Envelope** mode displays an actively acquiring waveform on-screen with the noise displayed.
- **Average** mode displays an actively acquiring waveform on-screen with the noise reduced like in Hi Res mode.

e. *Test all channels:* Repeat substeps a through d until all four input channels are verified.

3. *Remove the test hookup:* Disconnect the probe from the channel input and the probe-adjustment terminal.

Verify the Time Base

Equipment Required: One P6138 probe.

Prerequisites: None.

Procedure:

1. *Install the test hookup and preset the oscilloscope controls:*
   a. *Hook up the signal source:* Install the probe on **CH 1**. Connect the probe tip to **PROBE ADJ SIGNAL** on the front panel; leave the probe ground unconnected. (See Figure A-3 on page A-34.)
   b. *Initialize the oscilloscope:*
      - Press save/recall **SETUP**.
      - Press the main menu button **Recall Factory Setup**; then press the side menu button **OK Confirm Factory Init**.
   c. *Modify default settings:*
      - Press **AUTOSET** to obtain a viewable, triggered display.
      - Set the horizontal **SCALE** to 200 µs.
      - Press **VERTICAL MENU**.
      - Press the main menu button **Bandwidth**. Then press the side menu button **20 MHz**.
      - Press **CLEAR MENU** to remove the vertical menu from the screen.
2. *Verify that the time base operates:* Confirm the following statements.
   a. One period of the square-wave probe-compensation signal is about five horizontal divisions on-screen for the 200 µs horizontal scale setting (set in step 1c).
   b. Rotating the horizontal **SCALE** knob clockwise expands the waveform on-screen (more horizontal divisions per waveform period), and that counterclockwise rotation contracts it, and that returning the horizontal scale to 200 µs returns the period to about five divisions.

c. The horizontal **POSITION** knob positions the signal left and right on-screen when rotated.

3. *Remove the test hookup:* Disconnect the probe from the channel input and the probe-adjust terminal.

Verify the Main and Delayed Trigger Systems

Equipment Required: One P6138 probe.

Prerequisites: None.

Procedure:

1. *Install the test hookup and preset the oscilloscope controls:*

   a. *Hook up the signal source:* Install the probe on **CH 1**. Connect the probe tip to **PROBE ADJ SIGNAL** on the front panel; leave the probe ground unconnected. (See Figure A-3 on page A-34.)

   b. *Initialize the oscilloscope:*

      - Press save/recall **SETUP**.
      - Press the main menu button **Recall Factory Setup**.
      - Press the side menu button **OK Confirm Factory Init**.

   c. *Modify default settings:*

      - Press **AUTOSET** to obtain a viewable, triggered display.
      - Set the horizontal **SCALE** for the **M** (main) time base to 200 µs.
      - Press **VERTICAL MENU**.
      - Press the main menu button **Bandwidth**. Then press the side menu button **20 MHz**.
      - Press **TRIGGER MENU**.
      - Press the main menu button **Mode & Holdoff**.
      - Press the side menu button **Normal**.
      - Press **CLEAR MENU** to remove the menus from the screen.

2. *Verify that the main trigger system operates:* Confirm that the following statements are true.

   - The trigger level readout for the main trigger system changes with the trigger **MAIN LEVEL** knob.
   - The trigger-level knob can trigger and untrigger the square-wave signal as you rotate it. (Leave the signal *un*triggered.)
   - Pressing **SET LEVEL TO 50%** triggers the signal that you just left untriggered. (Leave the signal triggered.)

3. *Verify that the delayed trigger system operates:*

   a. *Select the delayed time base:*

      - Press **HORIZONTAL MENU**.
      - Press the main menu button **Time Base**.
      - Press the side menu button **Delayed Triggerable**; then press the side menu button **Delayed Only**.
      - Set the horizontal **SCALE** for the **D** (delayed) time base to 200 µs.

   b. *Select the delayed trigger level menu:*

      - Press **SHIFT**; then press **DELAYED TRIG**.
      - Press the main menu button **Level**; then press the side menu button **Level**.

   c. *Confirm that the following statements are true*:

      - The trigger-level readout for the delayed trigger system changes with the general purpose knob.
      - The general purpose knob can trigger and untrigger the square-wave probe-compensation signal as you rotate it. (Leave the signal *un*triggered.)
      - Pressing the side menu button **Set to 50%** triggers the probe-compensation signal that you just left untriggered. (Leave the signal triggered.)

   d. *Verify the delayed trigger counter:*

      - Press the main menu button **Delay by *Time***.
      - Press the side menu button **Delay by Events**.
      - Use the General Purpose knob to enter an event count of 325 events.
      - Verify that the trigger **READY** indicator on the front panel flashes about once every second as the waveform is updated on-screen.

4. *Remove the test hookup:* Disconnect the standard-accessory probe from the channel input and the probe-adjust terminal.

Performance Tests

This subsection contains a collection of procedures for checking that the TDS 400 Digitizing Oscilloscopes perform as warranted.

The procedures are arranged in four logical groupings: *Signal Acquisition System Checks, Time Base System Checks, Triggering System Checks*, and *Output Ports Checks*. They check all the characteristics that are designated as checked in Section 1, *Specification.* (The characteristics that are checked appear in **boldface** type under *Warranted Characteristics* in Section 1.)

These procedures *extend* the confidence level provided by the basic procedures described on page A-29. The basic procedures should be done first, then these procedures performed if desired.

Prerequisites

The tests in this subsection comprise an extensive, valid confirmation of performance and functionality when the following requirements are met:

- The cabinet must be installed on the digitizing oscilloscope.
- You must have performed and passed the procedures under *Self Tests,* found on page A-32, and those under *Functional Tests,* found on page A-33.
- A signal-path compensation must have been done within the recommended calibration interval and at a temperature within ±5°C of the present operating temperature. (If at the time you did the prerequisite *Self Tests,* the temperature was within the limits just stated, consider this prerequisite met.)
- The digitizing oscilloscope must have been last adjusted at an ambient temperature between +20°C and +30°C, must have been operating for a warm-up period of at least 20 minutes, and must be operating at an ambient temperature between 0°C and +50°C. (The warm-up requirement is usually met in the course of meeting the first prerequisite listed above.)

Related Information—Read *General Instructions* and *Conventions* that start on page A-29. Also, if you are not familiar with operating this digitizing oscilloscope, read *At a Glance* in Section 3 of this manual before doing any of these procedures.

Equipment Required

These procedures use external, traceable signal sources to directly check warranted characteristics. The required equipment list follows this introduction.

Table A-25: Test Equipment

Item Number and Description	Minimum Requirements	Example	Purpose
1 Attenuator,10X (two required)	Ratio: 10X; impedance 50 Ω; connectors: female BNC input, male BNC output	Tektronix part number 011-0059-02	Signal Attenuation
2 Attenuator, 5X (two required)	Ratio: 5X; impedance 50 Ω; connectors: female BNC input, male BNC output	Tektronix part number 011-0060-02	Signal Attenuation
3 Termination, 50 Ω	Impedance 50 Ω; connectors: female BNC input, male BNC output	Tektronix part number 011-0049-01	Checking Delay Between Channels
4 Termination, 75 Ω	Impedance 75 Ω; connectors: female BNC input, male BNC output	Tektronix part number 011-0102-01	Used to Test Video Option 05 Equipped Instruments Only
5 Cable, Precision Coaxial (two required)	50 Ω, 36 in, male to male BNC connectors	Tektronix part number 012-0482-00	Signal Interconnection
6 Cable, Coaxial	75 Ω, 36 in, male to male BNC connectors	Tektronix part number 012-1338-00	Used to Test Video Option 05 Equipped Instruments Only
7 Connector, Dual-Banana (two required)	Female BNC to dual banana	Tektronix part number 103-0090-00	Various Accuracy Tests
8 Connector, BNC "T"	Male BNC to dual female BNC	Tektronix part number 103-0030-00	Checking Trigger Sensitivity
9 Coupler, Dual-Input	Female BNC to dual male BNC	Tektronix part number 067-0525-02	Checking Delay Between Channels
10 Generator, DC Calibration	Variable amplitude to ±110 V; accuracy to 0.1%	Data Precision 8200, with 1 kV option installed	Checking DC Offset, Gain, and Measurement Accuracy
11 Generator, Leveled Sine-Wave, Medium-Frequency	200 kHz to 250 MHz; Variable amplitude from 5 mV to 4 V p-p into 50 Ω	TEKTRONIX SG 503 Leveled Sine Wave Generator[1]	Checking Trigger Sensitivity at low frequencies
12 Generator, Leveled Sine-Wave, High-Frequency	250 MHz to 500 MHz; Variable amplitude from 5 mV to 4 V p-p into 50 Ω; 6 MHz reference	TEKTRONIX SG 504 Leveled Sine Wave Generator[1] with SG 504 Output Head	Checking Analog Bandwidth and Trigger Sensitivity at high frequencies

[1]**Requires a TM 500 or TM 5000 Series Power Module Mainframe.**

Table A-25: Test Equipment (Cont.)

Item Number and Description	Minimum Requirements	Example	Purpose
13 Generator, Time Mark	Variable marker frequency from 10 ms to 10 ns; accuracy within 2 ppm	TEKTRONIX TG 501 Time Mark Generator[1]	Checking Sample-Rate and Delay-time Accuracy
14 Probe, 10X, included with this instrument	A P6138 probe	Tektronix number P6138	Signal Interconnection
15 Generator, Video Signal	Provides NTSC/PAL compatible outputs	TEKTRONIX TSG 1001	Checking Video Trigger Sensitivity

[1]Requires a TM 500 or TM 5000 Series Power Module Mainframe.

Signal Acquisition System Checks

These procedures check those characteristics that relate to the signal-acquisition system and are listed as checked under *Warranted Characteristics* in Appendix B, *Specification.*

Check Accuracy of Offset (Zero Setting)

Equipment Required: None.

Prerequisites: The oscilloscope must meet the prerequisites listed on page A-39.

1. *Preset the instrument controls:*
   a. *Initialize the oscilloscope:*
      - Press save/recall **SETUP**.
      - Press the main menu button **Recall Factory Setup**.
      - Press the side menu button **OK Confirm Factory Init**.
   b. *Modify the default settings:*
      - Set the horizontal **SCALE** to 1 ms.
      - Press **SHIFT**; then **ACQUIRE MENU**.
      - Press the main menu button **Mode**; then press the side menu button **Hi Res**.
      - Press **DISPLAY**.
      - Press the main menu button **Graticule**; then press the side menu button **Frame**.
      - Press **CURSOR**.
      - Press the main menu button **Function**; then press the side menu button **H Bars**.
      - Press **CLEAR MENU**.
2. *Confirm input channels are within limits for offset accuracy at zero offset:* Do the following substeps—test CH 1 first, *skipping substep a since CH 1 is already set up to be checked from step 1.*
   a. *Select an unchecked channel:* Press **WAVEFORM OFF** to remove the channel just confirmed from the display. Then, press the front-panel button that corresponds to the channel you are to confirm.

Table A-26: DC Offset Accuracy (Zero Setting)

Vertical Scale Setting	Vertical Position and Offset Setting[1]	Offset Accuracy Limits
1 mV	0	±0.9 mV
10 mV	0	±1.8 mV
100 mV	0	±18 mV
1 V	0	±180 mV

[1]Vertical position is set to 0 divisions and vertical offset to 0 V when the oscilloscope is initialized in step 1.

b. *Set the vertical scale:* Set the vertical **SCALE** to one of the settings listed in Table A-26 that is not yet checked. (Start with the first setting listed.)

c. *Display the test signal:* The baseline DC test level was initialized for all channels in step 1 and is displayed as you select each channel and its vertical scale. Be sure *not* to use the vertical **POSITION** knob while checking any channel for accuracy of offset, since varying the position invalidates the check.

d. *Measure the test signal:* Rotate the general purpose knob to superimpose the active cursor over the baseline DC test level. (Ignore the other cursor.)

e. Read the measurement results at the absolute (@:) cursor readout, not the delta (Δ:) readout on screen.

f. *Check against limits:* Do the following subparts in the order listed.

- CHECK that the measurement results are within the limits listed for the current vertical scale setting.
- Repeat substeps b through f until all vertical scale settings settings listed in Table A-26 are checked for the channel under test.

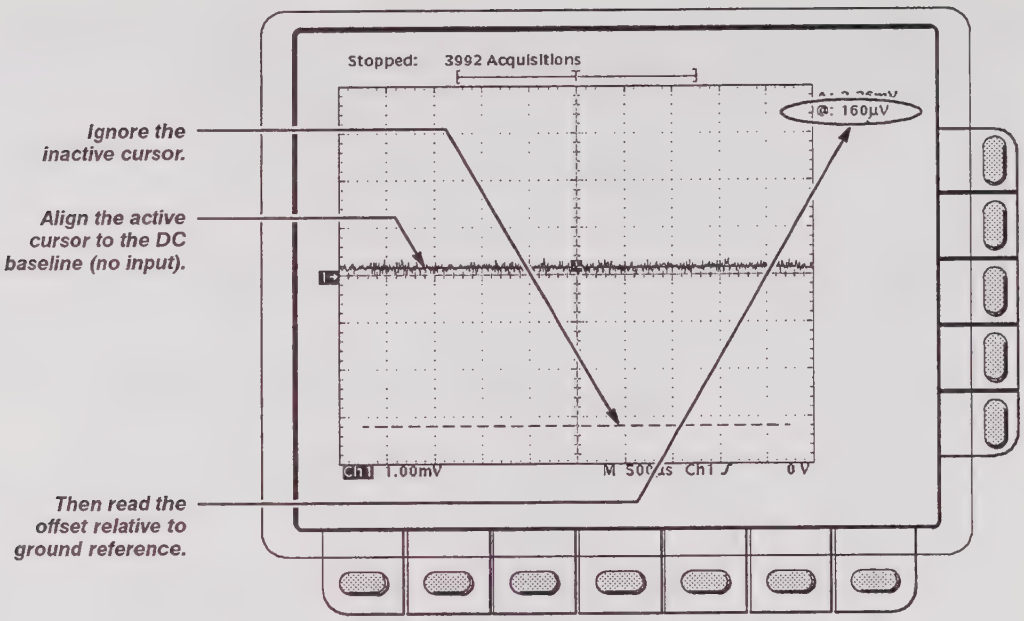

Ignore the inactive cursor.
Align the active cursor to the DC baseline (no input).
Then read the offset relative to ground reference.
Stopped: 3992 Acquisitions
@: 160µV
Ch1 1.00mV
M 500µs Ch1 ƒ 0 V

Figure A-4: Measurement of DC Offset Accuracy at Zero Setting

g. *Test all channels:* Repeat substeps a through f for all input channels.

3. *Disconnect the hookup:* No hookup was required.

Check DC Gain and Voltage Measurement Accuracy

WARNING

Performance of this procedure requires input voltages up to 108 VDC. Be sure to set the DC calibration generator to 0 volts before connecting, disconnecting, and/or moving the test hookup during the performance of this procedure.

Equipment Required: Two dual-banana connectors (Item 7), one BNC T connector (Item 8), one DC calibration generator (Item 10), and two precision coaxial cables (Item 5).

Prerequisites: The oscilloscope must meet the prerequisites listed on page A-39.

Procedure:

1. *Install the test hookup and preset the instrument controls:*

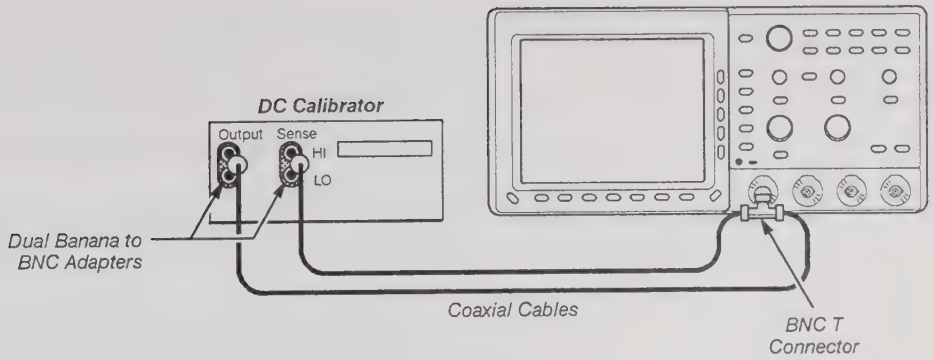


Figure A-5: Initial Test Hookup

a. *Hook up the test-signal source:*

- Set the output of a DC calibration generator to 0 volts.
- Connect the output of a DC calibration generator through a dual-banana connector followed by a 50 Ω precision coaxial cable to one side of a BNC T connector.
- Connect the Sense output of the generator through a second dual-banana connector followed by a 50 Ω precision coaxial cable to other side of the BNC T connector. Now connect the BNC T connector to **CH 1**.

b. *Initialize the oscilloscope:*

- Press save/recall **SETUP**.
- Press the main menu button **Recall Factory Setup**.
- Press the side menu button **OK Confirm Factory Init**.

c. *Modify the default settings:*

- Press **SHIFT**; then **ACQUIRE MENU**.
- Press the main menu button **Mode**; then press the side menu button **Average 16**.
- Press **CURSOR**.
- Press the main menu button **Function**; then press the side menu button **H Bars**.
- Press **DISPLAY**.
- Press the main menu button **Graticule**; then press the side menu button **Frame**.

2. *Confirm input channels are within limits for DC delta voltage accuracy:* Do the following substeps—test CH 1 first, *skipping substep a since CH 1 is already selected from step 1.*

   a. *Select an unchecked channel:*

- *Set the generator output to 0 V.*
- Press **WAVEFORM OFF** to remove the channel just confirmed from the display.
- Press the front-panel button that corresponds to the next channel you are to confirm.
- Move the test hook up to the channel you select.

b. *Display the test signal:*

- Press **VERTICAL MENU**. Press the main menu button **Position**.
- Turn the **General Purpose** knob to set the vertical position to –2.5 divisions.

c. *Measure the test signal:*

- Press **CURSOR**. Use the **general purpose** knob to precisely align the active cursor to the DC baseline level on screen.
- Set the generator output to 500 mV.
- Press **TOGGLE**. Use the **general purpose** knob to precisely align the alternate cursor to the 500 mV DC test level on screen.
- Press **CLEAR MENU**. Read the measurement results from the delta (Δ:) readout, not the absolute (@:) readout. See Figure A-6 on page A-46.

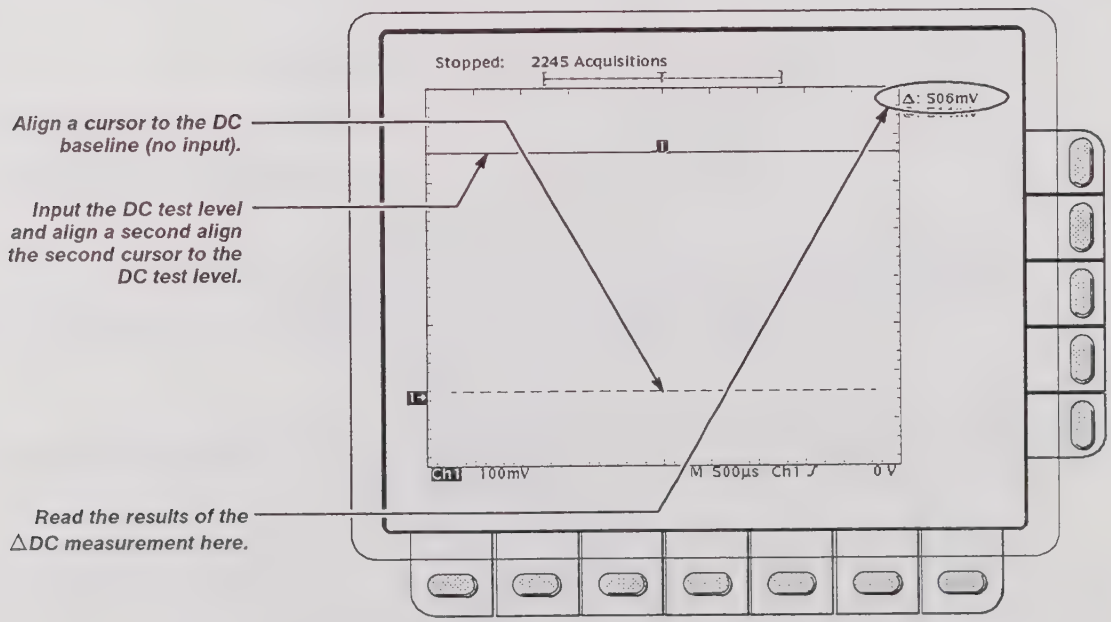

Align a cursor to the DC baseline (no input).
Input the DC test level and align a second align the second cursor to the DC test level.
Read the results of the ΔDC measurement here.
Stopped: 2245 Acquisitions
Δ: 506mV
Ch1 100mV
M 500µs Ch1 ƒ 0 V

Figure A-6: Measurement of the DC Accuracy for Delta Measurements

d. *Check against limits:* CHECK that the Δ: readout on screen is within 484 mV to 516 mV.

e. *Test all channels:* Repeat substeps a through d for all four channels.

3. *Reestablish the initial test hookup setup:*

   a. *Hook up the test-signal source:*

      - Set the output of a DC calibration generator to 0 volts.
      - Move the BNC T connector back to **CH 1**.

   b. *Initialize the oscilloscope:*

      - Press save/recall **SETUP**.
      - Press the main menu button **Recall Factory Setup**.
      - Press the side menu button **OK Confirm Factory Init**.

   c. *Modify the default settings:*

      - Press **SHIFT**; then **ACQUIRE MENU**.
      - Press the main menu button **Mode**; then press the side menu button **Average**. Use the **General Purpose** knob to set the number of averages to 16.
      - Press **DISPLAY**.
      - Press the main menu button **Graticule**; then press the side menu button **Frame**.

4. *Confirm input channels are within limits for DC accuracy at maximum offset and position:* Do the following substeps—test CH 1 first, *skipping substep a since CH 1 is already selected from step 3.*

   a. *Select an unchecked channel:*

      - Press **WAVEFORM OFF** to remove the channel just confirmed from the display.
      - Press the front-panel button that corresponds to the channel you are to confirm.
      - *Set the generator output to 0 V.*
      - Move the test hookup to the channel you select.

   b. *Turn on the measurement Mean for the channel:*

      - Press **MEASURE**, then press the main menu button **Select Measurement for CHx**.
      - Press the side menu button **more** until the menu label **Mean** appears in the side menu (its icon is shown at the left). Press the side menu button **Mean**.
      - Press **CLEAR MENU**.

c. *Set its vertical scale:* Set the vertical **SCALE** to one of the settings listed in Table A-27 that is not yet checked. (Start with the first setting listed.)

Table A-27: DC Accuracy

Scale Setting	Position Setting (Divs)	Offset Setting	Generator Setting	Accuracy Limits
1 V	−5	+100 V	+108 V	+107.22 V to +108.78 V
	+5	−100 V	−108 V	−107.22 V to −108.78 V
200 mV	−5	+10 V	+11.6 V	+11.504 V to +11.696 V
	+5	−10 V	−11.6 V	−11.504 V to −11.696 V
5 mV	−5	+1 V	+1.040 V	+1.0340 V to +1.0460 V
	+5	−1 V	−1.040 V	−1.0340 V to −1.0460 V

d. *Display the test signal:*

- Press **VERTICAL MENU**. Press the main menu button **Position**.
- Turn the **General Purpose** knob to set the vertical position to −5 divisions. The baseline level will move off screen.
- Press the main menu button **Offset**.
- Use the **General Purpose** knob to set vertical offset to the positive-polarity setting listed in the table for the current vertical scale setting. The baseline level will remain off screen.
- Set the generator to the level and polarity indicated in the table for the vertical scale, position, and offset settings you have made. The DC test level should appear on screen. (If it doesn't return, the DC accuracy check is failed for the current vertical scale setting of the current channel.)

e. *Measure the test signal:* Press **CLEAR MENU**. Read the measurement results at the **Mean** measurement readout. See Figure A-7.

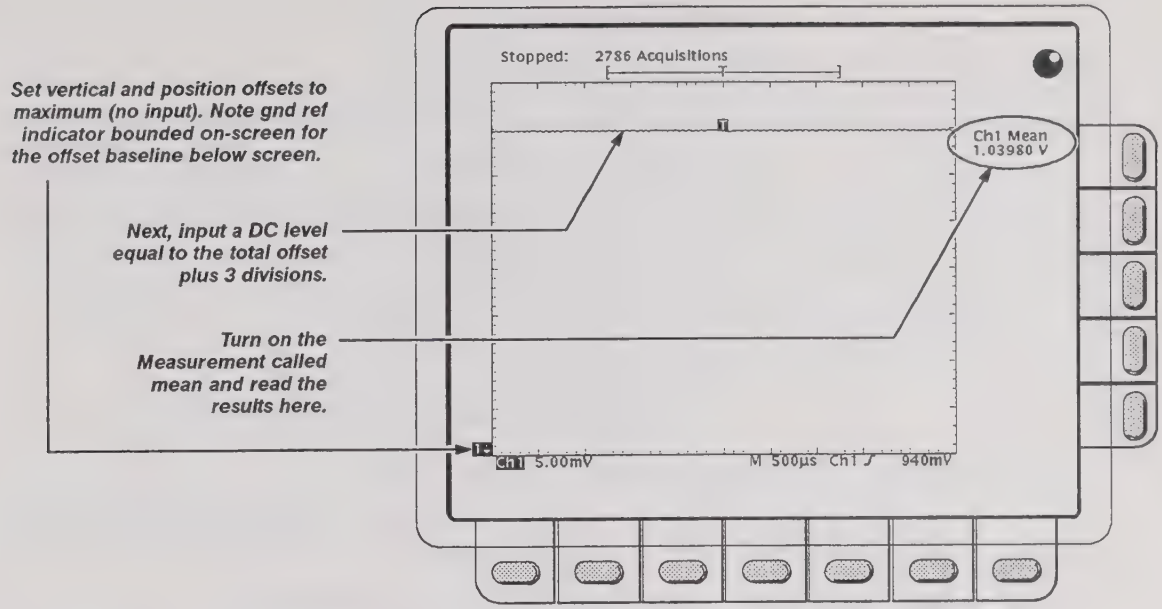

Set vertical and position offsets to maximum (no input). Note gnd ref indicator bounded on-screen for the offset baseline below screen.
Next, input a DC level equal to the total offset plus 3 divisions.
Turn on the Measurement called mean and read the results here.
Stopped: 2786 Acquisitions
Ch1 Mean
1.03980 V
Ch1 5.00mV
M 500µs Ch1 ƒ 940mV

Figure A-7: Measurement of DC Accuracy at Maximum Offset and Position

f. *Check against limits:*

- CHECK that the readout for the measurement **Mean** readout on screen is within the limits listed for the current vertical scale and position/offset/generator settings.
- Repeat step d, reversing the polarity of the position, offset, and generator settings as is listed in the table.
- CHECK that the **Mean** measurement readout on screen is within the limits listed for the current vertical scale setting and position/offset/generator settings.
- Repeat substeps c through f until all vertical scale settings settings listed in Table A-27 is checked for the channel under test.

g. *Test all channels:* Repeat substeps a through f for all four channels.

5. *Disconnect the hookup:*

   a. *Set the generator output to 0 V.*

   b. Then disconnect the cable from the generator output at the input connector of the channel last tested.

Check Analog Bandwidth

Equipment Required: One medium-frequency leveled sine-wave generator (Item 11), one 50 Ω precision cable (Item 5), and two 10X attenuators (Item 1).

TDS 460 Only: One high-frequency leveled sine-wave generator and its leveling head (Item 12).

Prerequisites: *See page A-39.*

Procedure:

1. *Install the test hookup and preset the instrument controls:*

   a. *Initialize the oscilloscope:*

   - Press save/recall **SETUP**. Then press the main menu button **Recall Factory Setup**.
   - Press the side menu button **OK Confirm Factory Init**.

   b. *Modify the default settings:*

   - TDS 420: Set the horizontal **SCALE** to 10 µs.
     TDS 460: Set the horizontal **SCALE** to 50 ns.
   - Press **TRIGGER MENU**.
   - Press main menu button **COUPLING**; then press the side menu button **Noise Rej**.
   - Press **SHIFT**; then **ACQUIRE MENU**.
   - Press the main menu button **Mode**; then press the side menu button **Average 16**.
   - Press **Measure**. Now press the main menu button **High-Low Setup**; then press the side menu button **Min-Max**.

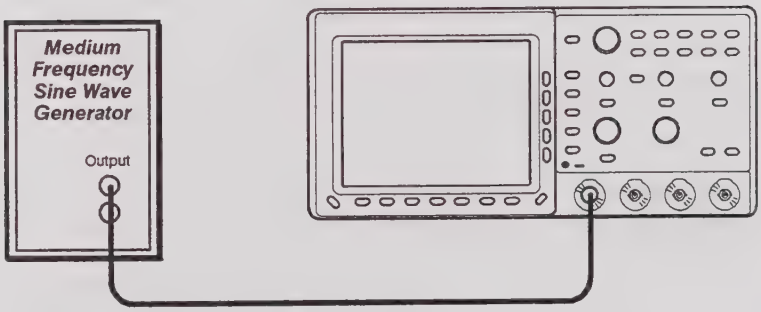


Figure A-8: TDS 420: Initial Test Hookup

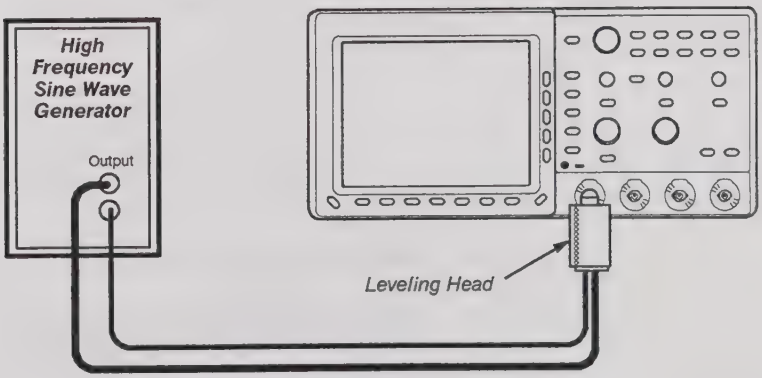


Figure A-9: TDS 460: Initial Test Hookup

c. *Hook up the test-signal source:*

- **TDS 420:** Connect, through a 50 Ω precision cable, the sine-wave output of a medium-frequency leveled sine-wave generator to **CH 1**. Set the output of the generator to a reference frequency of 50 kHz.
- **TDS 460:** Connect, through its leveling head, the sine-wave output of a high-frequency leveled sine-wave generator to **CH 1**. Set the output of the generator to a reference frequency of 6 MHz.

2. *Confirm the input channels are within limits for analog bandwidth:* Do the following substeps—test CH 1 first, *skipping substeps a and b since CH 1 is already set up for testing from step 1.*

a. *Select an unchecked channel:*

- Press **WAVEFORM OFF** to remove the channel just confirmed from display.
- Press the front-panel button that corresponds to the channel you are to confirm.
- Move the leveling head to the channel you select.

b. *Match the trigger source to the channel selected:*

- Press **TRIGGER MENU**.
- Press the main menu button **Source**.
- Press the side menu button that corresponds to the channel selected.

c. *Set its input impedance:*

- Press **VERTICAL MENU**; then press the main menu button **Coupling**.
- Press the side menu button Ω to toggle it to the 50 Ω setting.

d. *Set the vertical scale:* Set the vertical **SCALE** to one of the settings listed in Table A-28 not yet checked. (Start with the 100 mV setting.)

e. *Display the test signal:* Do the following subparts to first display the reference signal and then the test signal.

- Press **MEASURE**; then press the main menu button **Select Measurement for CHx**.
- Now press the side menu button **more** until the menu label **Pk-Pk** appears in the side menu (its icon is shown at the left). Press the side menu button **Pk-Pk**.
- Press **CLEAR MENU**.
- Set the generator output so the CHx Pk-Pk readout equals the reference amplitude in Table A-28 that corresponds to the vertical scale set in substep d.

- Press the front-panel button **SET LEVEL TO 50%** as necessary to trigger a stable display.

f. *Measure the test signal:*

When using Table A-28, be sure to make the test frequency settings that corresponds to the model of oscilloscope that you are checking, namely, the TDS 420 or TDS 460.

- Increase the frequency of the generator output to the test frequency in Table A-28 that corresponds to the vertical scale set in substep d.
- **TDS 420:** Set the horizontal **SCALE** to 5 ns.
  TDS 460: Set the horizontal **SCALE** to 2 ns.
- Press **SET LEVEL TO 50%** as necessary to trigger the display.
- Read the results at the CHx Pk-Pk readout, which will automatically measure the amplitude of the test signal. (See Figure A-10.)

Table A-28: Analog Bandwidth

Vertical Scale	Attenuators (10X)	Reference Amplitude	Test Frequency		Test Limits
			TDS 420	TDS 460	
100 mV	none	600 mV (6 divisions)	150 MHz	350 MHz	≥424 mV
1 V	none	5 V (5 divisions)	150 MHz	350 MHz	≥3.535 V
500 mV	none	3 V (6 divisions)	150 MHz	350 MHz	≥2.121 V
200 mV	none	1.2 V (6 divisions)	150 MHz	350 MHz	≥848 mV
50 mV	1	300 mV (6 divisions)	150 MHz	350 MHz	≥212 mV
20 mV	1	120 mV (6 divisions)	150 MHz	350 MHz	≥84 mV
10 mV	1	60 mV (6 divisions)	150 MHz	350 MHz	≥42 mV
5 mV	2	30 mV (6 divisions)	150 MHz	350 MHz	≥21 mV
2 mV	2	12 mV (6 divisions)	110 MHz	250 MHz	≥8.4 mV
1 mV	2	6 mV (6 divisions)	90 MHz	100 MHz	≥4.2 mV

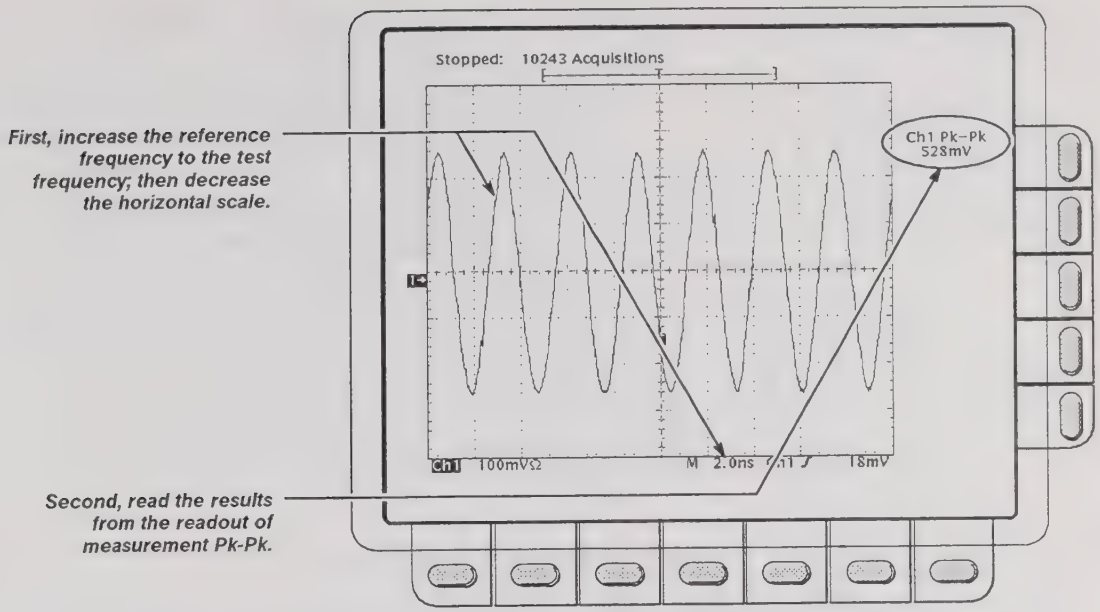

First, increase the reference frequency to the test frequency; then decrease the horizontal scale.
Second, read the results from the readout of measurement Pk-Pk.
Stopped: 10243 Acquisitions
Ch1 Pk-Pk 528mV
Ch1 100mVΩ
M 2.0ns
18mV

Figure A-10: Measurement of Analog Bandwidth

g. *Check against limits:*

- CHECK that the **Pk-Pk** readout on screen is within the limits listed in Table A-28 for the current vertical scale setting.
- **TDS 420:** When finished checking, set the horizontal **SCALE** back to the 10 μs setting.
- **TDS 460:** When finished checking, set the horizontal **SCALE** back to the 50 ns setting.

STOP

Checking each channel's bandwidth at all vertical scale settings is time consuming and unnecessary. You may skip checking the remaining vertical scale settings in Table A-28 (that is, skip the following substep, h) if this digitizing oscilloscope has performed as follows:

- Passed the 100 mV vertical scale setting just checked in this procedure.
- Passed the *Verify Internal Adjustment, Self Compensation, and Diagnostics* procedure found under *Self Tests,* on page A-32.

NOTE

Passing the signal path compensation confirms the signal path for all vertical scale settings for all channels. Passing the internal diagnostics ensures that the factory-set adjustment constants that control the bandwidth for each vertical scale setting have not changed.

h. *Check remaining vertical scale settings against limits (optional):*

- If desired, finish checking the remaining vertical scale settings for the channel under test by repeating substeps d through g for each of the remaining scale settings settings listed in Table A-28 the channel under test.
- When doing substep e, skip the subparts that turn on the CHx Pk-Pk measurement until you check a new channel.
- Install/remove 10X attenuators between the generator leveling head and the channel input as is needed to obtain the six division reference signals listed in the table.

i. *Test all channels:* Repeat substeps a through g for all four channels.

3. *Disconnect the hookup:* Disconnect the test hook up from the input connector of the channel last tested.

Check Delay Between Channels

Equipment Required: One medium-frequency leveled sine-wave generator (Item 11), one precision coaxial cable (Item 5), one 50 Ω terminator (Item 3), and a dual-input coupler (Item 9).

Prerequisites: *See page A-39.*

Procedure:

DO NOT use the vertical position knob to reposition any channel while doing this check. To do so invalidates the test.

1. *Install the test hookup and preset the instrument controls:*

a. *Initialize the front panel;*

- Press save/recall **SETUP**.
- Press the main menu button **Recall Factory Setup**.
- Press the side menu button **OK Confirm Factory Init**.

b. *Modify the initialized front-panel control settings:*

- Do *not* adjust the vertical position of any channel during this procedure.
- Set the horizontal **SCALE** to 1 ns.
- Press **SHIFT**; then press **ACQUIRE MENU**.
- Press the main menu button **Mode**, and then press the side menu button **Average 16**.

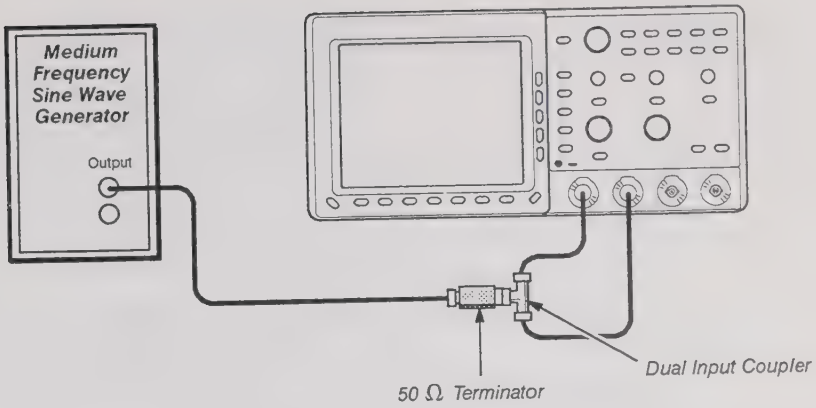


Figure A-11: Initial Test Hookup

c. *Hook up the test-signal source:*

- Connect, through a 50 Ω precision coaxial cable, followed by a 50 Ω termination, the sine wave output of a medium-frequency sine wave generator to a dual-input coupler.
- Connect the coupler to both **CH 1** and **CH 2**.

2. *Confirm CH 1 through CH 4 are within limits for channel delay:*

a. *Set up the generator:* Set the generator frequency to 250 MHz and the amplitude for about five divisions in CH 1.

Hint: as you are adjusting the generator amplitude, push **SET LEVEL TO 50%** frequently to speed up the updating of the waveform amplitude on screen.

b. *Save a CH 2 waveform:* Press **CH 2**; then press save/recall **WAVEFORM**. Now, press the main menu button **Save Waveform**; then press the side menu button **To Ref 2**.

c. *Save a CH 3 waveform:* Move the coupler from **CH 2** to **CH 3**, so that **CH 1** and **CH 3** are driven. Press **CH 3**; then press the side menu button **To Ref 3**.

d. *Display all test signals:*

- Press **WAVEFORM OFF** twice to remove CH 2 and CH 3 from the display.
- Move the coupler from **CH 3** to **CH 4**, so that CH 1 and CH 4 are driven. Press **CH 4** to display.
- Now, press the front-panel button **MORE**. Press the main menu buttons **Ref 2** and **Ref 3**.

e. *Measure the test signal:*

- Locate the point on the rising edge of the left-most waveform where it crosses the center horizontal graticule line. This is the *time reference point* for this waveform. Note the corresponding *time reference point* for right-most waveform. See Figure A-12.
- Press **CURSOR**; then press the side menu button **V Bars**.
- Press **CLEAR MENU**.
- Rotate the General Purpose knob to align one cursor to the *time reference point* of the left-most waveform edge and the other cursor to the *time reference point* of the right-most waveform edge. (Press **TOGGLE** to switch between the two cursors.) See Figure A-12.
- Read the measurement results at the Δ: cursor readout, not the @: readout on screen.

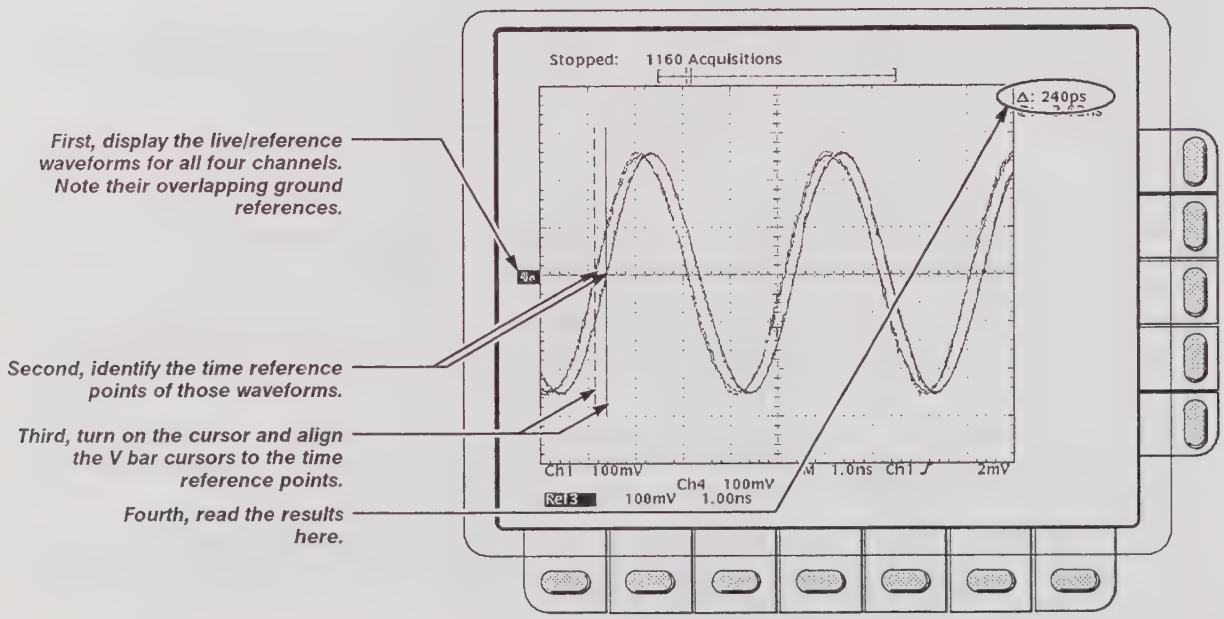

First, display the live/reference waveforms for all four channels. Note their overlapping ground references.
Second, identify the time reference points of those waveforms.
Third, turn on the cursor and align the V bar cursors to the time reference points.
Fourth, read the results here.
Stopped: 1160 Acquisitions
Δ: 240ps
Ch1 100mV
Ch4 100mV
1.0ns Ch1
2mV
Ref 3
100mV 1.00ns

Figure A-12: Measurement of Channel Delay

f. *Check all channels against limit:* CHECK that the cursor readout on screen is ≤450 ps. If the cursor readout is ≤200 ps, skip the next substep (g).

g. *Check CH 1 to CH 2 and CH 3 to CH 4 against limit:*

- Press **WAVEFORM OFF** four times to remove all waveforms.
- Press **CH 1**. Then press **MORE**, and then the main menu button **Ref 2**.

- Measure the delay between CH 1 and Ref 2 using the method described in substep e above.
- CHECK that the cursor readout on screen is ≤200 ps.
- Press **WAVEFORM OFF** twice to turn off CH 1 and Ref 2; then press **CH 4** to turn on CH 4.
- Press **MORE**; then press the main menu button **Ref 3** to display the CH 3 waveform stored in Ref 3.
- Measure the delay between Ref 3 and CH 4 using the method described in substep e above.
- CHECK that the cursor readout on screen is ≤200 ps.

3. *Disconnect the hookup:* Disconnect the cable from the generator output at the input connectors of the channels.

Time Base System Checks

These procedures check those characteristics that relate to the Main and Delayed time base system and are listed as checked under *Warranted Characteristics* in Appendix B, *Specification.*

Check Accuracy for Long-Term Sample Rate, Delay Time, and Delta Time Measurements

Equipment Required: One time-marker generator (Item 13) and one precision coaxial cable (Item 5).

Prerequisites: *See page A-39.*

Procedure:

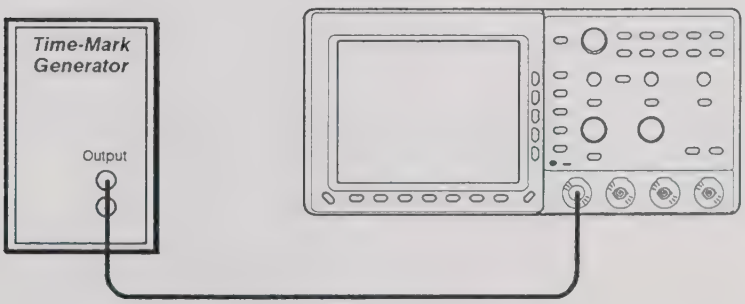


Figure A-13: Initial Test Hookup

1. *Install the test hookup and preset the instrument controls:*
   a. *Hook up the test-signal source*: Connect, through a 50 Ω precision coaxial cable, the time-mark output of a time-marker generator to **CH 1**. Set the output of the generator for 10 ms markers.

b. *Initialize the oscilloscope:*

- Press save/recall **SETUP**.
- Press the main menu button **Recall Factory Setup**.
- Press the side menu button **OK Confirm Factory Init**.

c. *Modify the initialized front-panel control settings:*

- Set the vertical **SCALE** to 500 mV.
- Press **VERTICAL MENU**; then press the main menu button **Coupling**. Press the side menu button Ω the coupling setting to **50** Ω.
- Press **SET LEVEL TO 50%**.
- Use the vertical **POSITION** knob to center the test signal on screen.
- Set the horizontal **SCALE** of the Main time base to 1 ms.
- Press **TRIGGER MENU**; then press the main menu button **Mode & Holdoff**. Now press the side menu button **Normal**.
- Press **SET LEVEL TO 50%**.
- Press horizontal **MENU**. Press the main menu button **Record Length**; then press the side menu button **1000 points in 20 divs**.
- Press the main menu button **Trigger Position**. Press the side menu button **Pretrigger**; then use the **General Purpose** knob to set pretrigger to 20%.

2. *Confirm Main and Delayed time bases are within limits for accuracies:*

a. *Display the test signal:*

- Adjust the horizontal **POSITION** to move the trigger **T** to the right and on to the screen. Continue to position the trigger **T** to align it to the center vertical graticule line.
- Press the main menu button **Time Base**.
- Press the side menu buttons **Delayed Only** and **Delayed Runs After Main**.

b. *Measure the test signal*:

- First set the horizontal **SCALE** of the **D** (delayed) time base to 1 ms. Then use the **General Purpose** knob to set delayed time to 10 ms.
- Set the horizontal **SCALE** of the **D** (delayed) time base to 500 ns.

c. *Check long-term sample rate and delay time accuracies against limits:* CHECK that the rising edge of the marker crosses the center horizontal graticule line at a point within ±3.0 divisions of center graticule.

d. *Check delta-time accuracy against limits:*

- Press the side menu button **Main Only**. Set horizontal **SCALE** to 5 ns.
- Set the output of the generator for 50 ns markers.

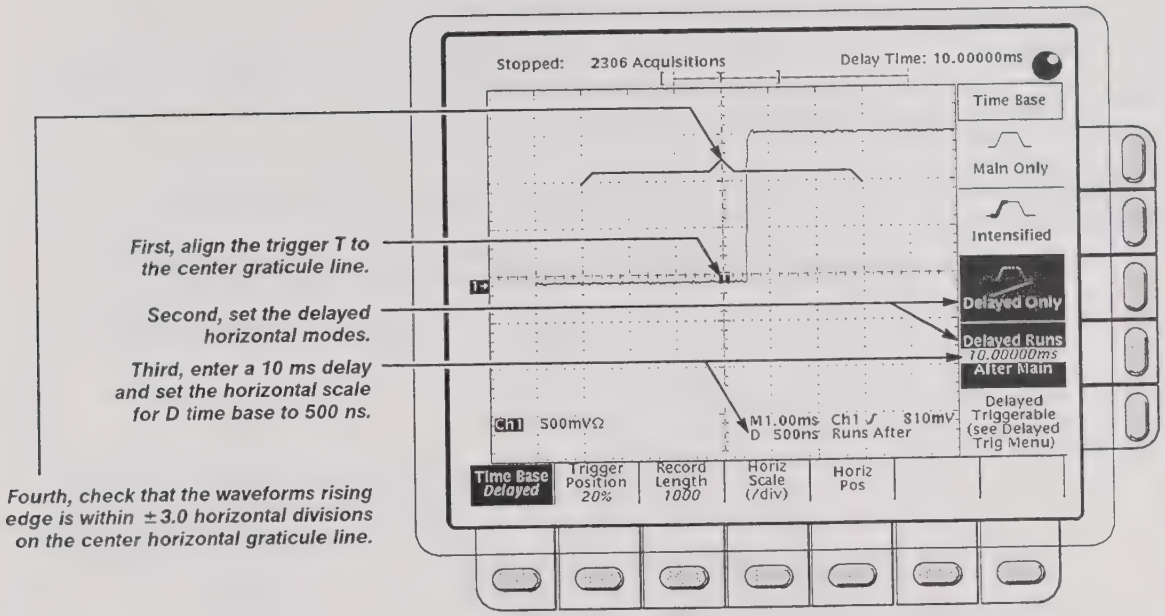

First, align the trigger T to the center graticule line.
Second, set the delayed horizontal modes.
Third, enter a 10 ms delay and set the horizontal scale for D time base to 500 ns.
Fourth, check that the waveforms rising edge is within ±3.0 horizontal divisions on the center horizontal graticule line.
Stopped: 2306 Acquisitions
Delay Time: 10.00000ms
Time Base
Main Only
Intensified
Delayed Only
Delayed Runs
10.00000ms
After Main
Delayed Triggerable (see Delayed Trig Menu)
Ch1 500mVΩ
M1.00ms Ch1 ƒ 810mV
D 500ns Runs After
Time Base Delayed
Trigger Position 20%
Record Length 1000
Horiz Scale (/div)
Horiz Pos

Figure A-14: Measurement of Accuracy—Long-Term and Delay-Time

- Press **SET LEVEL TO 50%**.
- Press **VERTICAL MENU**.
- Press the main menu button **Bandwidth**; then press the side menu button 100 MHz.
- Press **SHIFT**; then **ACQUIRE MENU**. Now press the main menu button **Mode**; then press the side menu button **Average**.
- Use the **General Purpose** knob to set the number of averages to 8.
- Press **MEASURE**.
- Press the main menu button **High-Low Setup**; then press the side menu button **Min-Max**.
- Press the main menu button **Select Measurement for Ch1**.
- Press the side menu button **–more–**, until **PERIOD** appears in the side menu. Press **PERIOD**.
- Press **CLEAR MENU**.

- CHECK that the readout for **CH 1 Per** is within 49.592 ns to 50.408 ns.

3. *Disconnect the hookup:* Disconnect the cable from the generator output at the input connector of **CH 1**.

Trigger System Checks

These procedures check those characteristics that relate to the Main and Delayed trigger systems and are listed as checked under *Warranted Characteristics* in Appendix B, *Specification.*

Check Accuracy, Trigger-level or Threshold, DC Coupled

Equipment Required: One DC calibration generator (Item 10), one BNC T connector (Item 8), and two precision coaxial cables (Item 5).

Prerequisites: The oscilloscope must meet the prerequisites listed on page A-39.

Procedure:

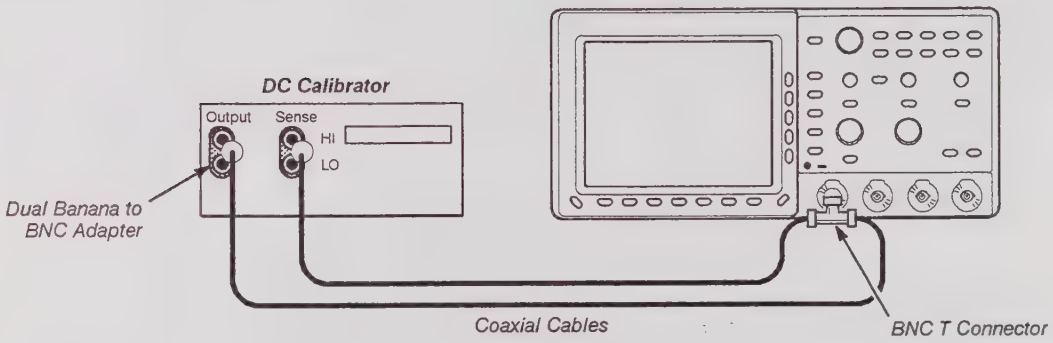


Figure A-15: Initial Test Hookup

1. *Install the test hookup and preset the instrument controls:*
   a. *Hook up the test-signal source:*
      - Set the output of a DC calibration generator to 0 volts.
      - Connect the output of a DC calibration generator through a dual-banana connector followed by a 50 Ω precision coaxial cable to one side of a BNC T connector.
      - Connect the Sense output of the generator, through a second dual-banana connector followed by a 50 Ω precision coaxial cable, to other side of the BNC T connector. Now connect the BNC T connector to **CH 1**.

b. *Initialize the oscilloscope:*

- Press save/recall **Setup**.
- Press the main menu button **Recall Factory Setup**.
- Press the side menu button **OK Confirm Factory Init**.

2. *Confirm Main trigger system is within limits for Trigger-level/Threshold accuracy:*

a. *Display the test signal:*

- Press **VERTICAL MENU**. Press the main menu button **Position**.
- Use the **General Purpose** knob to set vertical position to –3 divisions. The baseline level will move down three divisions.
- Press the main menu button **Offset**.
- Use the **General Purpose** knob to set vertical offset to +10 volts. The baseline level will move off-screen.
- Set the standard output of a DC calibration generator to +10 volts. The DC test level will appear on screen.

b. *Measure the test signal:*

- Press **SET LEVEL TO 50%**.
- Press **TRIGGER MENU**.
- Read the measurement results from the readout below the label **Level** in the menu, not the trigger readout in the graticule area.

c. *Check against limits:*

- CHECK that the **Level** readout in the main menu is within 9.922 V to 10.078 V, inclusive.
- Press **TRIGGER MENU**. Press the main menu button **Slope**; then press the side menu button for negative slope. (See icon at left.) Repeat substep b.
- CHECK that the **Level** readout in the main menu is within 9.922 V to 10.078 V, inclusive.

3. *Confirm Delayed trigger system is within limits for Trigger-level/Threshold accuracy:*

a. *Select the Delayed time base:*

- Press **HORIZONTAL MENU**.
- Press the main menu button **Time Base**.
- Press the side menu buttons **Delayed Only** and **Delayed Triggerable**.
- Set **D** (delayed) horizontal **SCALE** to 500 µs.

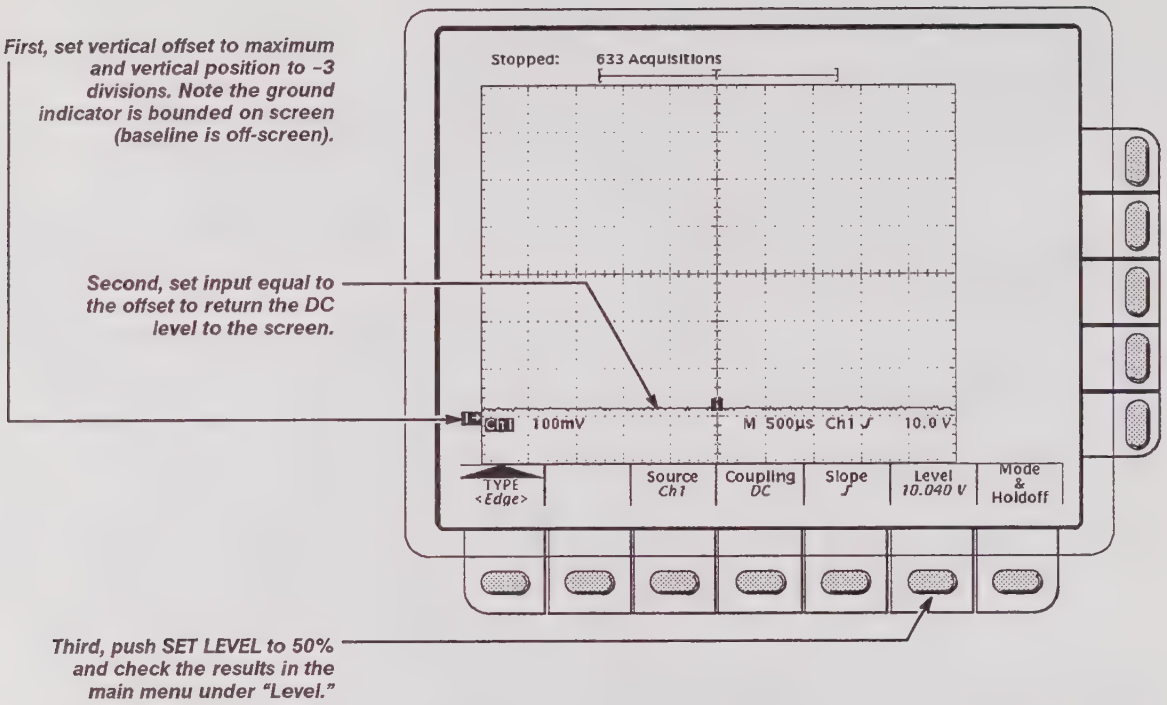

First, set vertical offset to maximum and vertical position to -3 divisions. Note the ground indicator is bounded on screen (baseline is off-screen).
Second, set input equal to the offset to return the DC level to the screen.
Third, push SET LEVEL to 50% and check the results in the main menu under "Level."
Stopped:
633 Acquisitions
Ch1 100mV
M 500µs Ch1 ƒ 10.0 V
TYPE <Edge>
Source Ch1
Coupling DC
Slope ƒ
Level 10.040 V
Mode & Holdoff

Figure A-16: Measurement of Trigger-Level Accuracy

b. *Select the Delayed trigger system:*

- Press **SHIFT**; then press the front-panel button **DELAYED TRIG**.
- Press the main menu button **Level**.

c. *Measure the test signal:* Press the *side menu button* **SET TO 50%**. Read the measurement results in the side menu below the label **Level**.

d. *Check against limits:* Do the following subparts in the order listed.

- CHECK that the **Level** readout in the side menu is within 9.922 V to 10.078 V, inclusive.
- Press the main menu button **Slope**; then press the side menu button for negative slope. (See icon at left.) Press the main menu button **Level**. Repeat substep c.
- CHECK that the **Level** readout in the side menu is within 9.922 V to 10.078 V, inclusive.

4. *Disconnect the hookup:*

a. *First set the output of the DC calibration generator to 0 volts.*

b. Then disconnect the cable from the generator output at the input connector of **CH 1**.

Sensitivity, Edge Trigger, DC Coupled

Equipment Required: One medium-frequency leveled sine-wave generator (Item 11), one high-frequency leveled sine-wave generator (Item 12), one precision 50 Ω coaxial cable (Item 5), one 10X attenuator (Item 1), and one 5X attenuator (Item 2).

Prerequisites: *See page A-39.*

Procedure:

1. *Install the test hookup and preset the instrument controls:*
   a. *Initialize the oscilloscope:*
      - Press save/recall **SETUP**.
      - Press the main menu button **Recall Factory Setup**.
      - Press the side menu button **OK Confirm Factory Init**.
   b. *Modify the initialized front-panel control settings:*
      - Set the horizontal **SCALE** for the **M** (main) time base to 20 ns.
      - Press **HORIZONTAL MENU**; then press the main menu button **Time Base**.
      - Press the side menu button **Delayed Only**; then press the side menu button **Delayed Triggerable**.
      - Set the horizontal **SCALE** for the **D** (delayed) time base to 20 ns; then press the side menu button **Main Only**.
      - Press **TRIGGER MENU**; then press the main menu button **Mode & Holdoff**. Now press the side menu button **Normal**.
      - Press **VERTICAL MENU**; then press the main menu button **Coupling**. Now press the side menu button Ω select the 50 Ω setting.
      - Press **SHIFT**; then press **ACQUIRE MENU**. Now press the main menu button **Mode**; then press the side menu button **Average 16**.

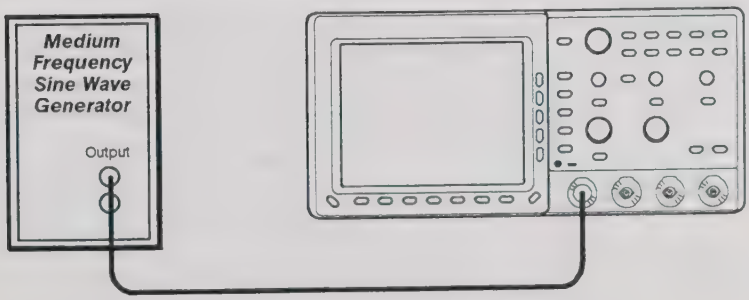


Figure A-17: Initial Test Hookup

2. *Confirm Main and Delayed trigger systems are within sensitivity limits (50 MHz):*

   a. *Display the test signal:*

   - Set the generator frequency to 50 MHz.
   - Press **MEASURE**.
   - Press the main menu button **High-Low Setup**; then press the side menu button **Min-Max**.
   - Press the main menu button **Select Measurement for Ch1**.
   - Press the side menu button **–more–** until **Amplitude** appears in the side menu (its icon is shown at the left). Press the side menu button **Amplitude**.

   - Adjust trigger **MAIN LEVEL** knob to obtain stable triggered waveform.
   - Press **CLEAR MENU**.
   - Set the test signal amplitude for about three divisions on screen. Now fine adjust the generator output until the **CH 1 Amplitude** readout indicates the amplitude is 350 mV. (Readout may fluctuate around 350 mV.)
   - Disconnect the 50 Ω precision coaxial cable at **CH 1** and reconnect it to **CH 1** through a 10X attenuator.

   b. *Check for Main trigger system for stable triggering at limits:*

   - Read the following definition: A stable trigger is one that is consistent; that is, one that results in a uniform, regular display triggered on the selected slope (positive or negative). This display should *not* have its trigger point switching between opposite slopes, nor should it "roll" across the screen. At horizontal scale settings of 2 ms/division and faster, **TRIG'D** will remain constantly lit. It will flash for slower settings.
   - Press **TRIGGER MENU**; then press the main menu button **Slope**.
   - Press **SET LEVEL TO 50%**. CHECK that a stable trigger is obtained for the test waveform on both the positive and negative slopes. (Use the side menu to switch between trigger slopes; use the trigger **MAIN LEVEL** knob to stabilize the trigger if required.)
   - Leave the Main trigger system triggered on the positive slope of the waveform before continuing to the next step.

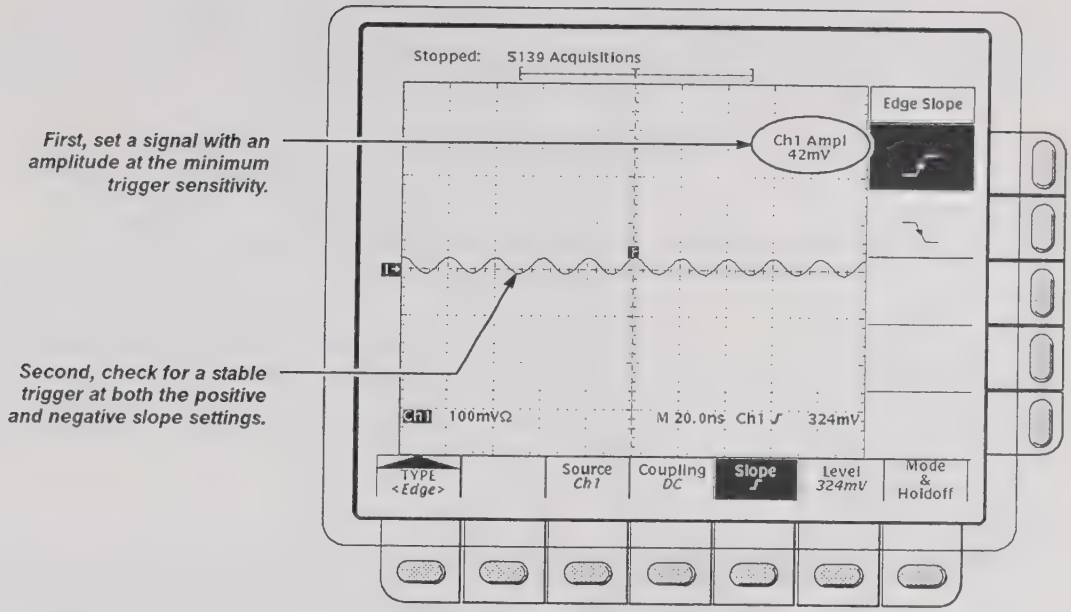

First, set a signal with an amplitude at the minimum trigger sensitivity.
Second, check for a stable trigger at both the positive and negative slope settings.
Stopped: 5139 Acquisitions
Edge Slope
Ch1 Ampl 42mV
Ch1 100mVΩ
M 20.0ns Ch1 ƒ 324mV
TYPE <Edge>
Source Ch1
Coupling DC
Slope
Level 324mV
Mode & Holdoff

Figure A-18: Measurement of Trigger Sensitivity

c. *Check delayed trigger system for stable triggering at limits:* Do the following subparts in the order listed.

- Press **HORIZONTAL MENU**; then press the main menu button **Time Base**. Now press the side menu button **Delayed Only**.
- Press **SHIFT**; then press **DELAYED TRIG**. Press the main menu button **Level**.
- Press the *side menu* button **SET TO 50%**. CHECK that a stable trigger is obtained for the test waveform for both the positive and negative slopes of the waveform. (Use the General Purpose knob to stabilize the trigger if required.) Press the main menu button **Slope**; then use the side menu to switch between trigger slopes.
- Leave the delayed trigger system triggered on the positive slope of the waveform before continuing to the next step. Also, return to the main time base: Press **HORIZONTAL MENU**; then press the main menu button **Time Base**. Now press the side menu button **Main Only**.

3. *Confirm that the Main and Delayed trigger systems are within sensitivity limits (at upper frequency limits):*

a. *Hook up the test-signal source:* Disconnect the hookup installed in step 1. Connect, through its leveling head, the signal output of a high-frequency leveled sine-wave generator to **CH 1**.

b. *Set the Main and Delayed Horizontal Scales:*

- Set the horizontal **SCALE** to 5 ns for the **M** (Main) time base.

- Press the side menu button **Delayed Only**.
- Set the horizontal **SCALE** to 2 ns for the **D** (Delayed) time base. Press the side menu button **Main Only**.

c. *Display the test signal:*

- **TDS 420:** Set the generator frequency to 350 MHz.
- **TDS 460:** Set the generator frequency to 500 MHz.
- Set the test signal amplitude for about five divisions on screen. Now fine adjust the generator output until the **CH 1 Amplitude** readout indicates the amplitude is 500 mV. (Readout may fluctuate around 500 mV.)
- Disconnect the leveling head at **CH 1** and reconnect it to **CH 1** through a 5X attenuator.

d. Repeat step 2, substeps b and c only.

4. *Confirm that the Main and Delayed trigger systems couple trigger signals from all channels:* Doing the procedure *Check Analog Bandwidth,* which begins of page A-49, checks coupling. If you have not done that procedure, do so after finishing this procedure. See the following note.

NOTE

Steps 1 through 3 confirmed trigger sensitivity for the Main and Delayed triggering systems using the CH 1 input. Doing the procedure Check Analog Bandwidth *ensures that trigger signals are coupled from all four channels.*

5. *Disconnect the hookup:* Disconnect the cable from the generator output at the input connector of the channel last tested.

Maximum Input Frequency, Auxiliary Trigger

Equipment Required: One medium-frequency leveled sine-wave generator (Item 11), two precision 50 Ω coaxial cables (Item 5), and a BNC T connector (Item 8).

Prerequisites: *See page A-39.*

Procedure:

1. *Install the test hookup and preset the instrument controls:*

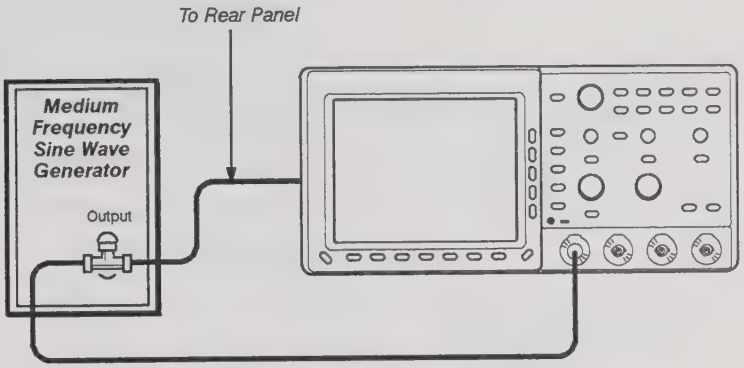


Figure A-19: Initial Test Hookup

a. *Initialize the oscilloscope:*
   - Press save/recall **SETUP**.
   - Press the main menu button **Recall Factory Setup**.
   - Press the side menu button **OK Confirm Factory Init**.

b. *Modify the initialized front-panel control settings:*
   - Set the vertical **SCALE** to 1 volt; set the horizontal **SCALE** to 20 ns.
   - Push **VERTICAL MENU**.
   - Press the main menu button **Coupling**. Push the side menu button Ω to toggle it to the 50 Ω setting.
   - Press **TRIGGER MENU**. Push the main-menu button **SOURCE**; then push the side-menu button **–more–** until **Auxiliary** appears in the side menu. Press the side-menu button **Auxiliary**.
   - Press the main menu button **Coupling**. Push the side menu button **AC**.

c. *Hook up the test-signal source:*
   - Connect a BNC T connector to the output of the sine-wave generator.
   - Connect one 50 Ω cable to one side of the BNC T connector; connect a second 50 Ω cable to the other side of the BNC T connector.

- Connect one of the cables just installed to **CH 1**; connect the other cable just installed to the **AUX TRIGGER** input at the rear panel.

2. *Confirm the Trigger input:*

   a. *Display the test signal:*

      - Set the generator for a 10 MHz, four division signal.

   b. *Check for Main trigger system for stable triggering at limits:*

      - Read the following definition: A stable trigger is one that is consistent; that is, one that results in a uniform, regular display triggered on the selected slope (positive or negative). This display should *not* have its trigger point switching between opposite slopes, nor should it "roll" across the screen.

First, set a signal with a four division amplitude and a 10 MHz frequency.

Second, check for a stable trigger at both the positive and negative slope settings.

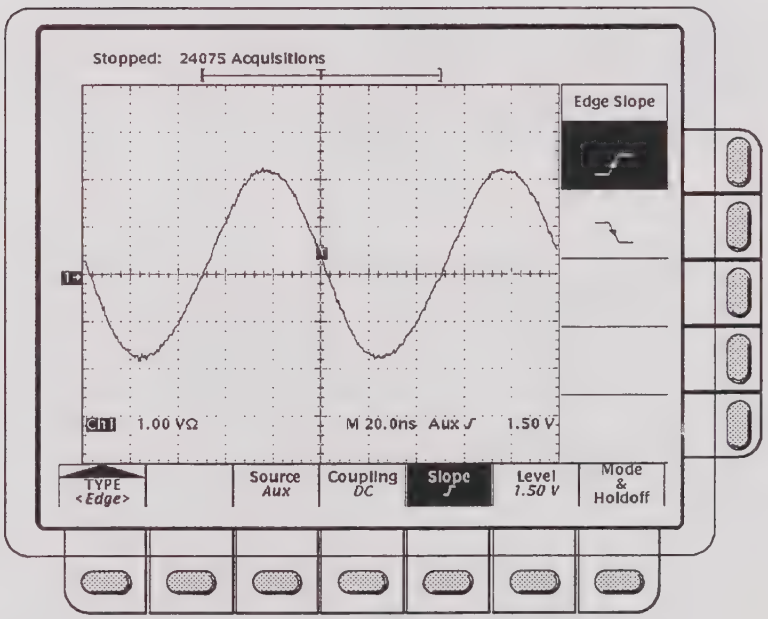


Figure A-20: Confirming Auxiliary Triggering at Maximum Triggering Frequency

3. *Disconnect the hookup:* Disconnect the cable from the generator output at the input connector of the channel last tested.

Check Video Trigger Sensitivity (Option 05 Equipped Models Only)

Equipment Required: One NTSC format video generator (Item 15), 75 Ω coaxial cable (Item 6), and one 75 Ω terminator (Item 4).

Prerequisites: *See page A-39.*

Procedure:

1. *Install the test hookup and preset the instrument controls:*
   a. *Initialize the instrument:*
      - Press save/recall **SETUP**.
      - Press the main menu button **Recall Factory Setup**.
      - Press the side menu button **OK Confirm Factory Init**.
   b. *Modify the default setup:*
      - Set the vertical **SCALE** to 500 mV.
      - Set the horizontal **SCALE** to 20 μs.
      - Press **HORIZONTAL MENU**.
      - Press the main menu button **Record Length**.
      - Press the side menu button **5000 points in 100 divs**.

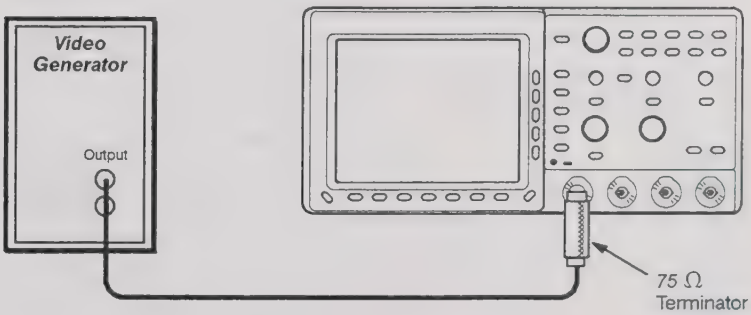


Figure A-21: Initial Test Hookup

   c. *Hook up the test-signal source:* Connect, through a 75 Ω precision coaxial cable, followed by a 75 Ω terminator, the output of a NTSC format video generator to CH 1.

2. *Confirm the video trigger system is within limits for:*
   a. *Display the test signal:*
      - Set video generator to NTSC format.
      - Set the output of the generator for a five step ramp with color burst.

- Press **SET TO 50%**. Use the trigger **MAIN LEVEL** knob to stabilize the display as required.
- Press **TRIGGER MENU**.
- Press the main menu button **Mode & Holdoff**. Then press the side menu button **Normal**.

b. *Fine adjust the sync pulse amplitude:* The amplitude of the TV waveform should now be about 2 divisions pk-pk. Do the following subparts to fine adjust the vertical gain until the sync pulses measure exactly 0.6 division pk-pk using the graticule:

- Press **VERTICAL MENU**.
- Press the main menu button **Fine Scale**.
- Use the General Purpose knob, adjust the fine gain until the sync pulse amplitude is 0.6 divisions measured using the graticule.

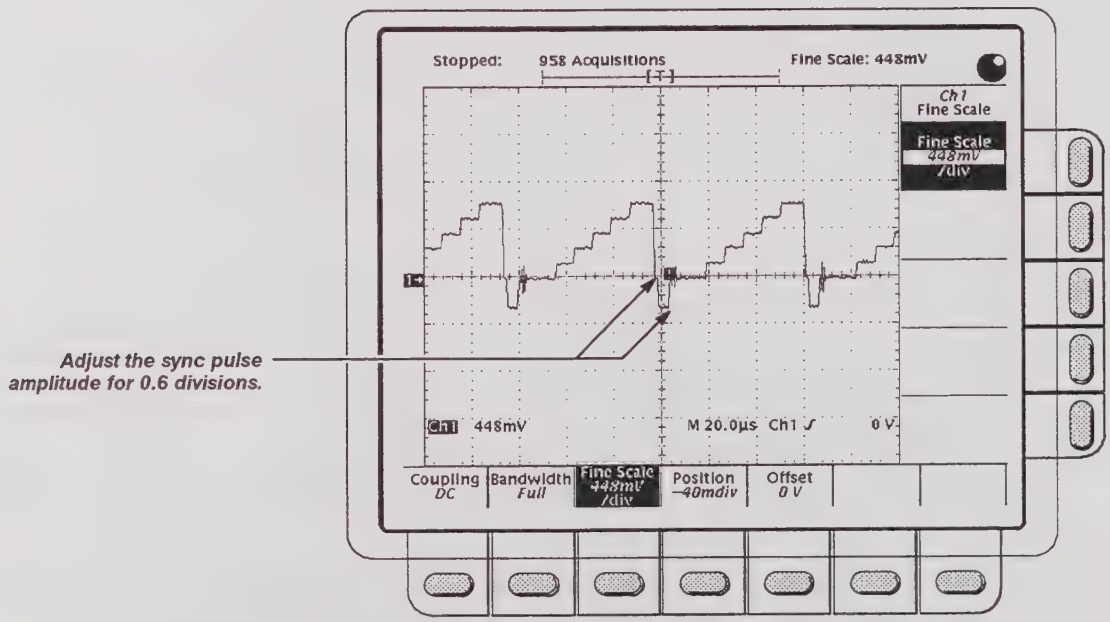


Figure A-22: Adjusting Sync Pulse Amplitude

c. *Check for stable triggering against limits:*

- Read the following definition: A stable trigger is one that is consistent; that is, one that results in a uniform, regular display triggered on the selected slope (positive or negative). This display should *not* have its trigger point switching between opposite slopes, nor should it "roll" across the screen. At horizontal scale settings of appropriate for viewing video waveforms, the **TRIG'D** light will remain constantly lit.

- Press **TRIGGER MENU**. Press the main menu button **Type** twice—first to pop up its menu and then to toggle it to **Video**.
- Press the main menu button **Class** to pop up its menu. Press it again as needed to toggle it to **NTSC**.
- Press the main menu button **Scan** to pop up its menu.
- Press the side menu button **Interlaced Field 1**. Center the display at mid screen.
- CHECK that a stable trigger is obtained with the last two lines of TV field 2 and the beginning of TV field 1 displayed. (If the last line is a full TV line duration (63.5 µs), then it is the end of field 2—see waveform R1 in Figure A-23.)
- Press the side menu button **Interlaced Field 2**. Center the display at mid screen.
- CHECK that a stable trigger is obtained with the last of TV field 1 and the beginning of TV field 2 displayed. (If the last line is a ½ TV line duration (31.75 µs), then it is the end of field 1—see waveform R2 in Figure A-23.)
- Press the side menu button **Non Interlaced Both Fields**.
- Press the main menu button **Mode and Holdoff**. Then press the side menu button **Holdoff**.
- Use the **General Purpose** knob to set the holdoff to **1**.

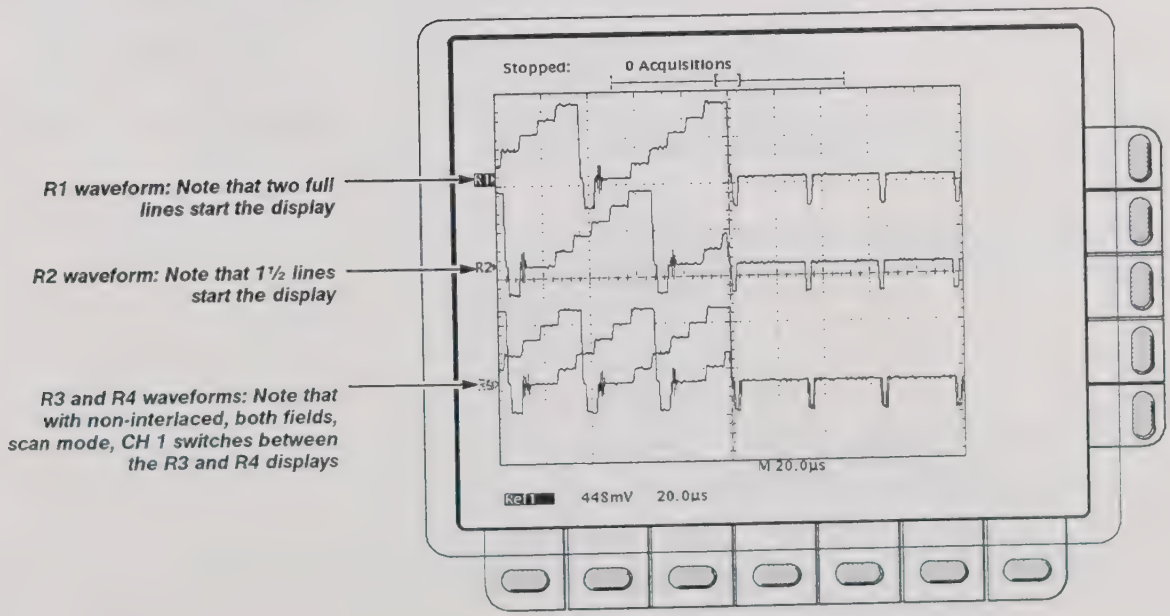

R1 waveform: Note that two full lines start the display
R2 waveform: Note that 1½ lines start the display
R3 and R4 waveforms: Note that with non-interlaced, both fields, scan mode, CH 1 switches between the R3 and R4 displays
Stopped:
0 Acquisitions
R1
R2
M 20.0µs
Ref 1
44.8mV
20.0µs

Figure A-23: Measurement of Video Sensitivity

- Rotate the horizontal **POSITION** control clockwise to move the ends of both fields to the center of the display.
- CHECK that a stable trigger is obtained while alternating between field 1 and field 2. (If the last line is alternating between a full TV line and ½ a line in duration (63.5 µs and 31.75 µs respectively), then triggering is occurring on both fields—see waveforms R3 and R4 in Figure A-23.)

d. *Check delay by lines:*

- Press the main menu button **Scan**.
- Press the side menu button **Interlaced Field One**.
- Rotate the horizontal **POSITION** control counter clockwise and align the trigger "**T**" to center screen
- Press the main menu button **TV Delay Mode**.
- Press the side menu button **Delay by Lines**.
- Use the General Purpose knob to set the line count to **10**.
- CHECK that the selected line is the first line that has the color burst signal.

e. *Check sync trigger:*

- Using the Vertical **POSITION** knob move the video waveform from the top to the bottom of the display.
- CHECK that the **TRIG'D** LED stays on and the waveform is stable.
- Using the Vertical **POSITION** knob return the waveform to the center of the display.

3. *Disconnect the hookup:* Disconnect the cable from the generator output at the input connector of **CH 1**.

Output Signal Checks

The procedure that follows checks the characteristics of the probe compensation signal that are listed as checked under *Warranted Characteristics* in Appendix B, *Specification*.

Check Probe Adjust Output

Equipment Required: One standard-accessory 10X probe (Item 14).

Prerequisites: See page A-39. Also, this digitizing oscilloscope must have passed *Check Accuracy—Long-Term Sample Rate, Delay time, Time Measurement* on page A-57 and *Check Accuracy for DC Gain and Voltage Measurements* on page A-44.

Procedure:

1. *Install the test hookup and preset the instrument controls:*

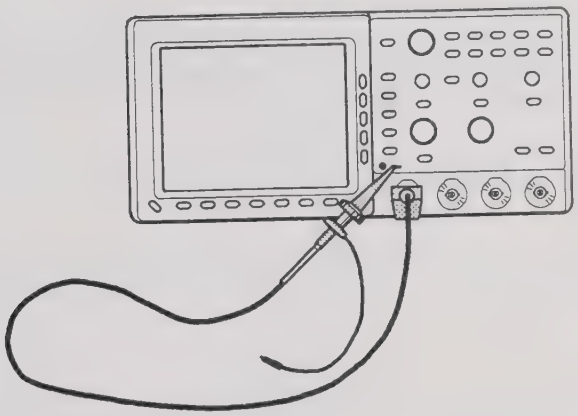


Figure A-24: Initial Test Hookup

a. *Hook up test-signal:* Install the standard-accessory probe on **CH 1**. Connect the probe tip to **PROBE ADJ** on the front panel; leave the probe ground unconnected.

b. *Initialize the oscilloscope:*

- Press save/recall **SETUP**.
- Press the main menu button **Recall Factory Setup**.
- Press the side menu button **OK Confirm Factory Init**.

c. *Modify the initialized front-panel control settings:*

- Press **AUTOSET**. Set the horizontal **SCALE** to 200 µs.
- Press **SHIFT**; then press **ACQUIRE MENU**.
- Press the main menu button **Mode**; then press the side menu button **Hi Res**.

2. *Confirm that the Probe Compensator signal is within limits for amplitude and frequency:*

   a. *Measure amplitude and frequency of the probe compensation signal:*

   - Press **MEASURE**; then press the main menu button **Select Measurement for Ch1**.

   - Repeatedly press the side menu button **–more–** until **Amplitude** appears in the side menu (its icon is shown at the left). Press the side menu button **Amplitude**.

   - Now repeatedly press the side menu button **–more–** until **Frequency** appears in the side menu (its icon is shown at the left). Press the side menu button **Frequency**.
   - Press **CLEAR MENU** to remove the menus from the display. See Figure A-25.

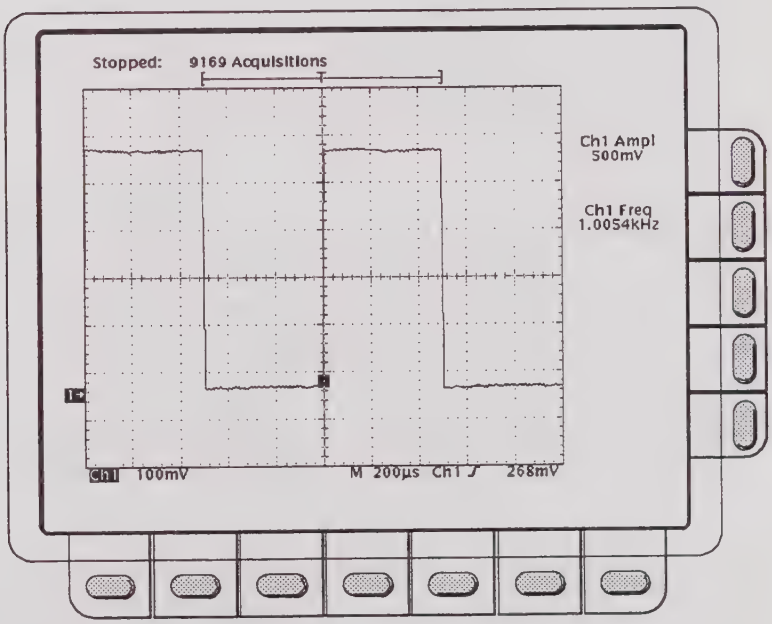


Figure A-25: Measurement of Probe Compensator Limits

   b. *Check against limits:* CHECK that the **CH 1 Freq** readout is within 950 Hz to 1.050 kHz, inclusive, and that the readout for **Ch1 Ampl** is within 475 mV to 525 mV, inclusive.

   c. *Disconnect the test hookup:* Remove the test probe as desired.

Appendix D: Algorithms

The Tektronix TDS Series Digitizing Oscilloscope can take 22 automatic measurements. By knowing how the instrument makes these calculations, you may better understand how to use your instrument and how to interpret your results.

Measurement Variables

The TDS Series Digitizing Oscilloscope uses a variety of variables in its calculations. These include:

High, Low

High is the value used as the 100% level in measurements such as fall time and rise time. For example, if you request the 10% to 90% rise time, then the oscilloscope will calculate 10% and 90% as percentages with *High* representing 100%.

Low is the value used as the 0% level in measurements such as fall time and rise time.

The exact meaning of *High* and *Low* depends on which of two calculation methods you choose from the Measure menu's **High-Low Setup** item. These are *Min-max* and *Histogram*.

Min-Max Method – defines the 0% and the 100% waveform levels as the lowest amplitude (most negative) and the highest amplitude (most positive) samples. The min-max method is useful for measuring frequency, width, and period for many types of signals. Min-max is sensitive to waveform ringing and spikes, however, and does not always measure accurately rise time, fall time, overshoot, and undershoot.

The min-max method calculates the High and Low values as follows:

$$High = Max$$

and

$$Low = Min$$

Histogram Method – attempts to find the highest density of points above and below the waveform's midpoint. It attempts to ignore ringing and spikes when determining the 0% and 100% levels. This method works well when measuring square waves and pulse waveforms.

The oscilloscope calculates the histogram-based *High* and *Low* values as follows:

1. It makes a histogram of the record with one bin for each digitizing level (256 total).

2. It splits the histogram into two sections at the halfway point between *Min* and *Max* (also called *Mid*).
3. The level with the most points in the upper histogram is the *High* value, and the level with the most points in the lower histogram is the *Low* value. (Choose the levels where the histograms peak for *High* and *Low*.)

   If *Mid* gives the largest peak value within the upper or lower histogram, then return the *Mid* value for both *High* and *Low* (this is probably a very low amplitude waveform).

   If more than one histogram level (bin) has the maximum value, choose the bin farthest from *Mid*.

This algorithm does not work well for two-level waveforms with greater than about 100% overshoot.

HighRef, MidRef, LowRef

The user sets the various reference levels, through the Measure menu's **Reference Level** selection. They include:

HighRef—the waveform's high reference level. Used in fall time and rise time calculations. Typically set to 90%. You can set it from 0% to 100%.

MidRef—the waveform's middle reference level. Typically set to 50%. You can set it from 0% to 100%.

LowRef—the waveform's low reference level. Used in fall and rise time calculations. Typically set to 10%. You can set it from 0% to 100%.

Mid2Ref—the middle reference level for a second waveform. Used in delay time calculations. Typically set to 50%. You can set it from 0% to 100%.

Other Variables

The oscilloscope also measures several values itself that it uses to help calculate measurements.

RecordLength—is the number of data points in the time base. You set it with the Horizontal menu **Record Length** item.

Start—is the location of the start of the measurement zone (X-value). It is 0.0 samples unless you are making a gated measurement. When you use gated measurements, it is the location of the left vertical cursor.

End—is the location of the end of the measurement zone (X-value). It is (*RecordLength* – 1.0) samples unless you are making a gated measurement. When you use gated measurements, it is the location of the right vertical cursor.

Hysteresis—is 10%. It is used in *MCross1*, *MCross2*, and *MCross3* calculations.

MCross Calculations

MCross1, MCross2, and MCross3—refer to the first, second, and third *MidRef* cross times, respectively. See Figure A-26.

Note that the polarity of the crossings does not matter for these variables, but the crossings will alternate in polarity; i.e., *MCross1* could be a positive or negative crossing, but if *MCross1* is a positive crossing, *MCross2* will be a negative crossing.

The oscilloscope calculates these values as follows:

1. Find the first *MidRefCrossing* in the measurement zone. This is *MCross1*.
2. Continuing from *MCross1*, find the next *MidRefCrossing* in the measurement zone of the opposite polarity of *MCross1*. This is *MCross2*.
3. Continuing from *MCross2*, find the next *MidRefCrossing* in the measurement zone of the same polarity as *MCross1*. This is *MCross3*.

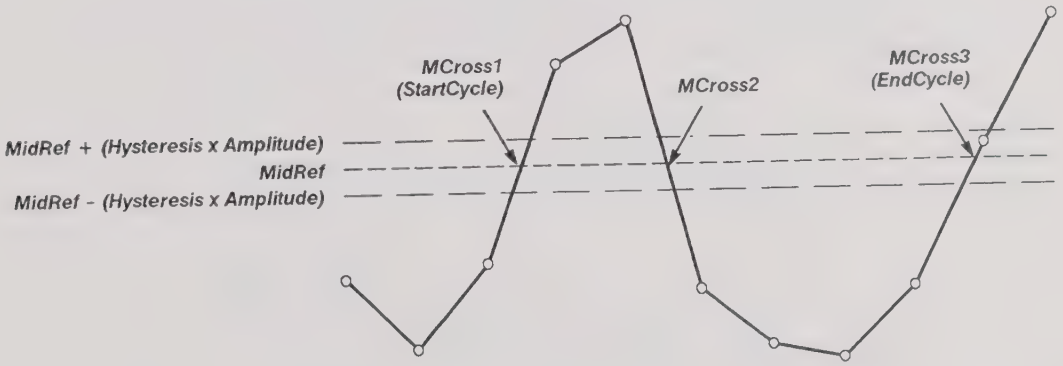


Figure A-26: MCross Calculations

MCross1Polarity—is the polarity of first crossing (no default). It can be rising or falling.

StartCycle—is the starting time for cycle measurements. It is a floating-point number with values between 0.0 and (*RecordLength* − 1.0), inclusive.

$$StartCycle = MCross1$$

EndCycle—is the ending time for cycle measurements. It is a floating-point number with values between 0.0 and (*RecordLength* − 1.0), inclusive.

$$EndCycle = MCross3$$

Waveform[<1 ... RecordLength>] – holds the acquired data.

TPOS – is the location of the sample just before the trigger point (the time reference zero sample). In other terms, it contains the domain reference location. This location is where time = 0.

TSOFF – is the offset between *TPOS* and the actual trigger point. In other words, it is the trigger sample offset. Values range between 0.0 and 1.0 samples. This value is determined by the instrument when it receives a trigger. The actual zero reference (trigger) location in the measurement record is at (*TPOS* + *TSOFF*).

Measurement Algorithms

The automated measurements are defined and calculated as follows:

Amplitude

$$Amplitude = High - Low$$

Burst Width

Timing measurement. The duration of a burst.

1. Find *MCross1* on the waveform. This is *MCrossStart*.
2. Find the last *MCross* (begin the search at *EndCycle* and search toward *StartCycle*). This is *MCrossStop*. This could be a different value from *MCross1*.
3. Compute $BurstWidth = MCrossStop - MCrossStart$

Cycle Mean

Amplitude (voltage) measurement. The mean over one waveform cycle. For non-cyclical data, you might prefer to use the Mean measurement.

If $StartCycle = EndCycle$ then return the (interpolated) value at *StartCycle*.

$$CycleMean = \frac{\int_{StartCycle}^{EndCycle} Waveform(t)dt}{(EndCycle - StartCycle) \times SampleInterval}$$

Cycle RMS

The true Root Mean Square voltage over one cycle.

If $StartCycle = EndCycle$ then $CycleRMS = Waveform[Start]$.

Otherwise,

$$CycleRMS = \sqrt{\frac{\int_{StartCycle}^{EndCycle} (Waveform(t))^2 dt}{(EndCycle - StartCycle) \times SampleInterval)}}$$

Delay

Timing measurement. The time between the *MidRef* crossings of two different traces.

Delay measurements are actually a group of measurements. To get a specific delay measurement, you must specify the target and reference crossing polarities, and the reference search direction.

Delay = the time from one *MidRef* crossing on the source waveform to the *Mid2Ref* crossing on the second waveform.

Fall Time

Timing measurement. The time taken for the falling edge of a pulse to drop from a *HighRef* value (default = 90%) to a *LowRef* value (default = 10%).

Figure A-27 shows a falling edge with the two crossings necessary to calculate a Fall measurement.

1. Searching from *Start* to *End*, find the first sample in the measurement zone greater than *HighRef*.
2. From this sample, continue the search to find the first (negative) crossing of *HighRef*. The time of this crossing is *THF*. (Use linear interpolation if necessary.)
3. From *THF*, continue the search, looking for a crossing of *LowRef*. Update *THF* if subsequent *HighRef* crossings are found. When a *LowRef* crossing is found, it becomes *TLF*. (Use linear interpolation if necessary.)
4. *FallTime* = *TLF* – *THF*

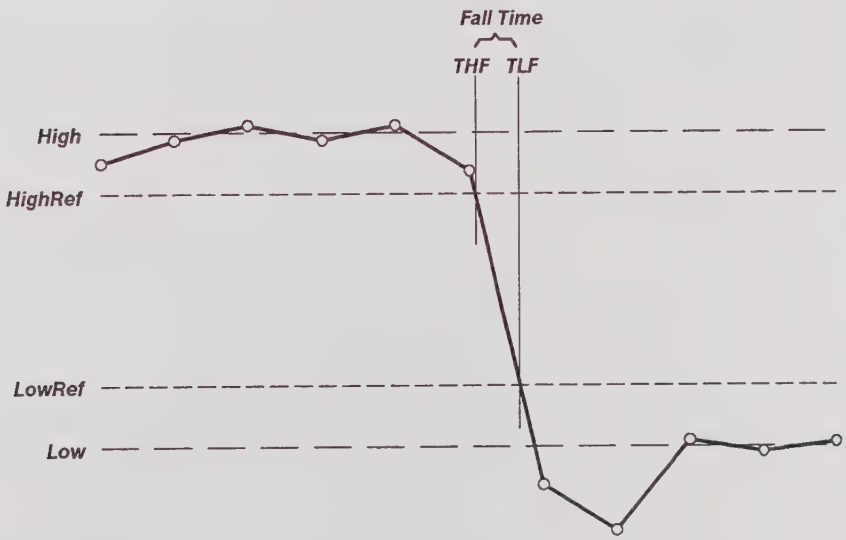


Figure A-27: Fall Time

Frequency

Timing measurement. The reciprocal of the period. Measured in Hertz (Hz) where 1 Hz = 1 cycle per second.

If *Period* = 0 or is otherwise bad, return an error.

Frequency = 1/*Period*

High

100% (highest) voltage reference value. (See "High, Low" earlier in this section)

Using the min-max measurement technique:

$$High = Max$$

Low

0% (lowest) voltage reference value calculated. (See "High, Low" earlier in this section)

Using the min-max measurement technique:

$$Low = Min$$

Maximum

Amplitude (voltage) measurement. The maximum voltage. Typically the most positive peak voltage.

Examine all *Waveform[ ]* samples from *Start* to *End* inclusive and set *Max* equal to the greatest magnitude *Waveform[ ]* value found.

Mean

The arithmetic mean for one waveform. Remember that one waveform is not necessarily equal to one cycle. For cyclical data you may prefer to use the cycle mean rather than the arithmetic mean.

if $Start = End$ then return the (interpolated) value at *Start*.

Otherwise,

$$Mean = \frac{\int_{Start}^{End} Waveform(t)\mathrm{d}t}{(End - Start) \times SampleInterval}$$

Minimum

Amplitude (voltage) measurement. The minimum amplitude. Typically the most negative peak voltage.

Examine all *Waveform[ ]* samples from *Start* to *End* inclusive and set *Min* equal to the smallest magnitude *Waveform[ ]* value found.

Negative Duty Cycle

Timing measurement. The ratio of the negative pulse width to the signal period expressed as a percentage.

NegativeWidth is defined in **Negative Width**, below.

If *Period* = 0 or undefined then return an error.

$$NegativeDutyCycle = \frac{NegativeWidth}{Period} \times 100\%$$

Negative Overshoot

Amplitude (voltage) measurement.

$$NegativeOvershoot = \frac{Low - Min}{Amplitude} \times 100\%$$

Note that this value should never be negative (unless High or Low are set out-of-range).

Negative Width

Timing measurement. The distance (time) between *MidRef* (default = 50%) amplitude points of a negative pulse.

If *MCross1Polarity* = '–'

then

$$NegativeWidth = (MCross2 - MCross1)$$

else

$$NegativeWidth = (MCross3 - MCross2)$$

Peak to Peak

Amplitude measurement. The absolute difference between the maximum and minimum amplitude.

$$PeaktoPeak = Max - Min$$

Period

Timing measurement. Time taken for one complete signal cycle. The reciprocal of frequency. Measured in seconds.

$$Period = MCross3 - MCross1$$

Positive Duty Cycle

Timing measurement. The ratio of the positive pulse width to the signal period, expressed as a percentage.

PositiveWidth is defined in **Positive Width**, following.

If $Period = 0$ or undefined then return an error.

$$PositiveDutyCycle = \frac{PositiveWidth}{Period} \times 100\%$$

Positive Overshoot

Amplitude (voltage) measurement.

$$PositiveOvershoot = \frac{Max - High}{Amplitude} \times 100\%$$

Note that this value should never be negative.

Positive Width

Timing measurement. The distance (time) between *MidRef* (default = 50%) amplitude points of a positive pulse.

If $MCross1Polarity = \text{'+'}$

then

$$PositiveWidth = (MCross2 - MCross1)$$

else

$$PositiveWidth = (MCross3 - MCross2)$$

Rise Time

Timing measurement. Time taken for the leading edge of a pulse to rise from a *LowRef* value (default = 10%) to a *HighRef* value (default = 90%).

Figure A-28 shows a rising edge with the two crossings necessary to calculate a Rise Time measurement.

1. Searching from *Start* to *End*, find the first sample in the measurement zone less than *LowRef*.
2. From this sample, continue the search to find the first (positive) crossing of *LowRef*. The time of this crossing is the low rise time or *TLR*. (Use linear interpolation if necessary.)
3. From *TLR*, continue the search, looking for a crossing of *HighRef*. Update *TLR* if subsequent *LowRef* crossings are found. If a *HighRef* crossing is found, it becomes the high rise time or *THR*. (Use linear interpolation if necessary.)
4. $RiseTime = THR - TLR$

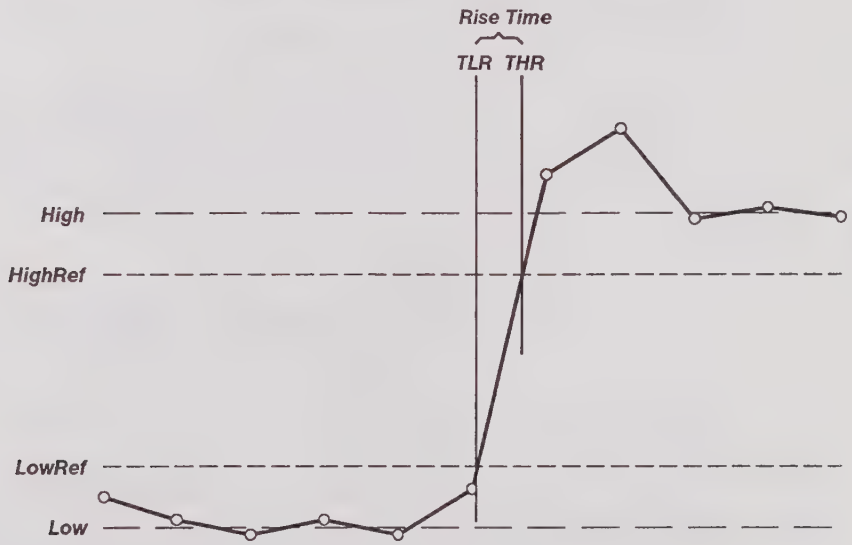


Figure A-28: Rise Time

RMS:

Amplitude (voltage) measurement. The true Root Mean Square voltage.

If *Start* = *End* then *RMS* = the (interpolated) value at *Waveform[Start]*.

Otherwise,

$$RMS = \sqrt{\frac{\int_{Start}^{End} (Waveform(t))^2 dt}{(End - Start) \times SampleInterval)}}$$

Measurements on Envelope Waveforms

Time measurements on envelope waveforms must be treated differently from time measurements on other waveforms, because envelope waveforms contain so many apparent crossings. Unless otherwise noted, envelope waveforms use either the minima or the maxima (but not both), determined in the following manner:

1. Step through the waveform from *Start* to *End* until the sample min and max pair *DO NOT* straddle *MidRef*.
2. If the pair > *MidRef*, use the minima, else use maxima.

   If all pairs straddle *MidRef*, use maxima. See Figure A-29.

The Burst Width measurement always uses both maxima and minima to determine crossings.

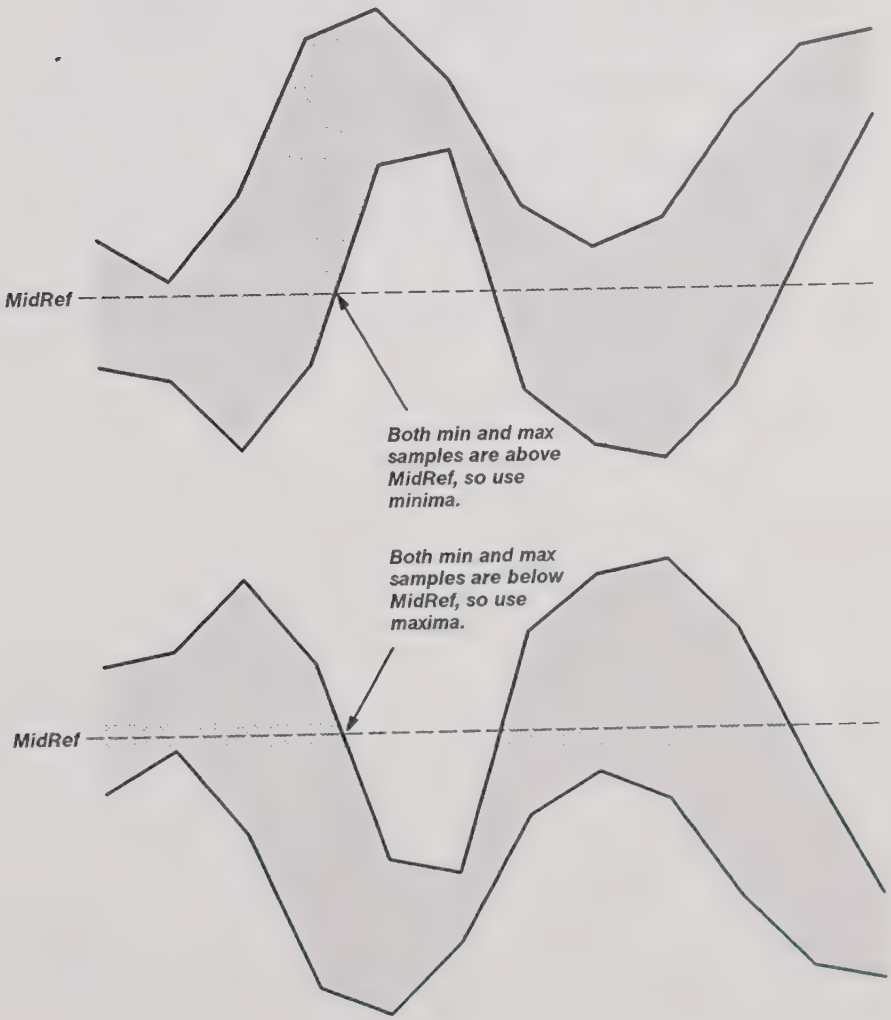

MidRef
Both min and max samples are above MidRef, so use minima.
Both min and max samples are below MidRef, so use maxima.
MidRef

Figure A-29: Choosing Minima or Maxima to Use for Envelope Measurements

Missing or Out-of-Range Samples

If some samples in the waveform are missing or off-scale, the measurements will linearly interpolate between known samples to make an "appropriate" guess as to the sample value. Missing samples at the ends of the measurement record will be assumed to have the value of the nearest known sample.

When samples are out of range, the measurement will give a warning to that effect (for example, "CLIPPING") if the measurement could change by extending the measurement range slightly. The algorithms assume the samples recover from an overdrive condition instantaneously.

For example, if *MidRef* is set directly, then *MidRef* would not change even if samples were out of range. However, if *MidRef* was chosen using the **%** choice from the Measure menu's **Set Levels in % Units** selection, then *MidRef* could give a "CLIPPING" warning.

Appendix E: Packaging for Shipment

If you ship the digitizing oscilloscope, pack it in the original shipping carton and packing material. If the original packing material is not available, package the instrument as follows:

- ☐ **Step 1:** Obtain a corrugated cardboard shipping carton with inside dimensions at least 15 cm (6 in) taller, wider, and deeper than the digitizing oscilloscope. The shipping carton must be constructed of cardboard with 170 kg (375 pound) test strength.
- ☐ **Step 2:** If you are shipping the digitizing oscilloscope to a Tektronix field office for repair, attach a tag to the digitizing oscilloscope showing the instrument owner and address, the name of the person to contact about the instrument, the instrument type, and the serial number.
- ☐ **Step 3:** Wrap the digitizing oscilloscope with polyethylene sheeting or equivalent material to protect the finish.
- ☐ **Step 4:** Cushion the digitizing oscilloscope in the shipping carton by tightly packing dunnage or urethane foam on all sides between the carton and the digitizing oscilloscope. Allow 7.5 cm (3 in) on all sides, top, and bottom.
- ☐ **Step 5:** Seal the shipping carton with shipping tape or an industrial stapler.

Appendix F: Factory Initialization Settings

The factory initialization settings function provide you a known state for the digitizing oscilloscope.

Settings

Factory initialization sets values as shown in Table A-29.

Table A-29: Factory Initialization Defaults

Control	Changed by Factory Init to
Acquire mode	Sample
Acquire repetitive signal	ON (Enable ET)
Acquire stop after	RUN/STOP button only
Acquire # of averages	16
Acquire # of envelopes	10
Channel selection	Channel 1 on, all others off
Cursor H Bar 1 position	10% of graticule height (–3.2 divs from the center)
Cursor H Bar 2 position	90% of the graticule height (+3.2 divs from the center)
Cursor V Bar 1 position	10% of the record length
Cursor V Bar 2 position	90% of the record length
Cursor function	Off
Cursor time units	Seconds
Delayed edge trigger coupling	DC
Delayed edge trigger level	0 V
Delayed edge trigger slope	Rising
Delayed edge trigger source	Channel 1
Delay trigger average #	16
Delay trigger envelope #	10

Table A-29: Factory Initialization Defaults (Cont.)

Control	Changed by Factory Init to
Delay time, delayed runs after main	4.0 ns
Delay time, delayed triggerable after main	4.0 ns
Delay events, triggerable after main	2
Delayed, delay by ...	Delay by Time
Delayed, time base mode	Delayed Runs After Main
Display format	YT
Display graticule type	Full
Display intensity – contrast	125%
Display intensity – text	60%
Display intensity – waveform	80%
Display intensity – overall	85%
Display interpolation filter	Sin(x)/x
Display style	Vectors
Display trigger "T"	On
Display variable persistence	500 ms
Edge trigger coupling	DC
Edge trigger level	0.0 V
Edge trigger slope	Rising
Edge trigger source	Channel 1
Horizontal – delay trigger position	50%
Horizontal – delay trigger record length	500 points (10 divs)
Horizontal – delay trigger time/div.	50 µs
Horizontal – main trigger position	50%
Horizontal – main trigger record length	500 points (10 divs)
Horizontal – main trigger time/div.	500 µs
Horizontal – time base	Main only

Table A-29: Factory Initialization Defaults (Cont.)

Control	Changed by Factory Init to
Main trigger holdoff	0%
Main trigger mode	Auto
Main trigger type	Edge
Math function (single wfm)	Invert (Inv)
Math operator (dual wfm)	+ for math1 and math3, – for math2
Math source 1 (single and dual)	Channel 1 (Ch1)
Math source 2	Channel 2 (Ch2)
Math type	Dual Wfm Math
Measure Delay to	Channel 1 (Ch1)
Measure Delay edges	Both rising and forward searching
Measure High-Low Setup	Histogram
Measure High Ref	90% and 0 V (units)
Measure Low Ref	10% and 0 V (units)
Measure Mid Ref	50% and 0 V (units)
Measure Mid2 Ref	50% and 0 V (units)
Pattern trigger Ch4/Ax2 input	X (don't care)
Saved setups	No change
Saved waveforms	No change
Vertical bandwidth (all channels)	Full
Vertical coupling (all channels)	DC
Vertical impedance (termination) (all channels)	1 MΩ
Vertical offset (all channels)	0 V
Vertical position (all channels)	0 divs.
Vertical volts/div. (all channels)	100 mV/div.
Zoom horizontal (all channels)	1.0X
Zoom horizontal lock	Live
Zoom horizontal position (all channels)	50% = .5 (the middle of the display)

Table A-29: Factory Initialization Defaults (Cont.)

Control	Changed by Factory Init to
Zoom state	Off
Zoom vertical (all channels)	1.0X
Zoom vertical position (all channels)	0 divs.

Appendix G: Remote Display

You can connect a remote display to the VGA 9-pin D connector on the rear panel. Table A-4 on page A-4 gives the part number of a properly shielded cable that is commercially available.

Because display manufacturers use different pin combinations and connectors, you may find the following information helpful.

Table A-30: VGA Output Connector Pins

Pin	Signal
2	Video (monochrome analog)
4	Horizontal sync @ 31.5 kHz (VGA rate)
5	Vertical sync
6, 7, 8	Ground

MANUAL CHANGE INFORMATION

At Tektronix, we continually strive to keep up with latest electronic developments by adding circuit and component improvements to our instruments as soon as they are developed and tested.

Sometimes, due to printing and shipping requirements, we can't get these changes immediately into printed manuals. Hence, your manual may contain new change information on following pages.

A single change may affect several sections. Since the change information sheets are carried in the manual until all changes are permanently entered, some duplication may occur. If no such change pages appear following this page, your manual is correct as printed.

Glossary & Index

Replace this page with the tab divider of the same name.

Glossary

AC ∿

AC coupling
A type of signal transmission that blocks the DC component of a signal but uses the dynamic (AC) component. Useful for observing an AC signal that is normally riding on a DC signal.

Accuracy
The closeness of the indicated value to the true value.

Acquisition
The process of sampling signals from input channels, digitizing the samples into data points, and assembling the data points into a waveform record. The waveform record is stored in memory. The trigger marks time zero in that process.

Acquisition interval
The time duration of the waveform record divided by the record length. The digitizing oscilloscope displays one data point for every acquisition interval.

Active cursor
The cursor that moves when you turn the general purpose knob. It is represented in the display by a solid line. The @ readout on the display shows the absolute value of the active cursor.

Aliasing
A false representation of a signal due to insufficient sampling of high frequencies or fast transitions. A condition that occurs when a digitizing oscilloscope digitizes at a sampling rate that is too slow to reproduce the input signal. The waveform displayed on the oscilloscope may have a lower frequency than the actual input signal.

Amplitude
The High waveform value less the Low waveform value.

Attenuation
The degree the amplitude of a signal is reduced when it passes through an attenuating device such as a probe or attenuator. That is, the ratio of the input measure to the output measure. For example, a 10X probe will attenuate, or reduce, the input voltage of a signal by a factor of 10.

Automatic trigger mode
A trigger mode that causes the oscilloscope to automatically acquire if triggerable events are not detected within a specified time period.

Autoset
A function of the oscilloscope that automatically produces a stable waveform of usable size. Autoset sets up front-panel controls based on the characteristics of the active waveform. A successful autoset will set the volts/div, time/div, and trigger level to produce a coherent and stable waveform display.

Average acquisition mode
In this mode the oscilloscope acquires and displays a waveform that is the averaged result of several acquisitions. That reduces the apparent noise. The oscilloscope acquires data as in the sample mode and then averages it according to a specified number of averages.

Bandwidth
The highest frequency signal the oscilloscope can acquire with no more than 3 dB (× .707) attenuation of the original (reference) signal.

Burst width
A timing measurement of the duration of a burst.

Channel
One type of input used for signal acquisition. The TDS 460 has four channels.

Coupling
The association of two or more circuits or systems in such a way that power or information can be transferred from one to the other. You can couple the input signal to the trigger and vertical systems several different ways.

Cursors
Paired markers that you can use to make measurements between two waveform locations. The oscilloscope displays the values (expressed in volts or time) of the position of the active cursor and the distance between the two cursors.

Cycle mean
An amplitude (voltage) measurement of the arithmetic mean over one cycle.

Cycle RMS
The true Root Mean Square voltage over one cycle.

DC

DC coupling
A mode that passes both AC and DC signal components to the circuit. Available for both the trigger system and the vertical system.

Delay measurement
A measurement of the time between the middle reference crossings of two different waveforms.

Delay time
The time between the trigger event and the acquisition of data.

Display system
The part of the oscilloscope that shows waveforms, measurements, menu items, status, and other parameters.

Edge Trigger
Triggering occurs when the oscilloscope detects the source passing through a specified voltage level in a specified direction (the trigger slope).

Envelope acquisition mode

A mode in which the oscilloscope acquires and displays a waveform that shows the variation extremes of several acquisitions.

Equivalent time sampling (ET)

A sampling mode in which the oscilloscope acquires signals over many repetitions of the event. The TDS 400 Series Digitizing Oscilloscopes use a type of equivalent time sampling called *random equivalent time sampling*. It utilizes an internal clock that runs asynchronously with respect to the input signal and the signal trigger. The oscilloscope takes samples continuously, independent of the trigger position, and displays them based on the time difference between the sample and the trigger. Although the samples are taken sequentially in time, they are random with respect to the trigger.

Fall time

A measurement of the time it takes for trailing edge of a pulse to fall from a HighRef value (typically 90%) to a LowRef value (typically 10%) of its amplitude.

Frequency

A timing measurement that is the reciprocal of the period. Measured in Hertz (Hz) where 1 Hz = 1 cycle per second.

Gated Measurements

A feature that lets you limit automated measurements to a specified portion of the waveform. You define the area of interest using the vertical cursors.

General purpose knob

The large front-panel knob in the upper left corner of the control area. You can use it to change the value of the assigned parameter.

GPIB (General Purpose Interface Bus)

An interconnection bus and protocol that allows you to connect multiple instruments in a network under the control of a controller. Also known as IEEE 488 bus. It transfers data with eight parallel data lines, five control lines, and three handshake lines.

Graticule

A grid on the display screen that creates the horizontal and vertical axes. You can use it to visually measure waveform parameters.

Ground (GND) coupling

Coupling option that disconnects the input signal from the vertical system.

Hardcopy

An electronic copy of the display in a format useable by a printer or plotter.

Hi Res acquisition mode

An acquisition mode in which the digitizing oscilloscope averages all samples taken during an acquisition interval to create a record point. That average results in a higher-resolution, lower-bandwidth waveform. That mode only works with real-time, non-interpolated sampling.

High

The value used as 100% in automated measurements (whenever high ref, mid ref, and low ref values are needed as in fall time and rise time measurements). May be calculated using either the min/max or the histogram method. With the min/max method (most useful for general waveforms), it is the maximum value found. With the histogram method (most useful for pulses), it refers to the most common value found above the mid point. See *Appendix D: Algorithms* for details.

Holdoff, trigger

A specified amount of time after a trigger signal that elapses before the trigger circuit will accept another trigger signal. That helps ensure a stable display.

Horizontal bar cursors

The two horizontal bars that you position to measure the voltage parameters of a waveform. The oscilloscope displays the value of the active (moveable) cursor with respect to ground and the voltage value between the bars.

Interlacing

The act of drawing a single video frame or picture using two separate video signals called field one and field two. That process draws the video picture line by line horizontally using information from field one for all the odd number lines and information from field two for all the even lines.

Interpolation

The way the digitizing oscilloscope calculates values for record points when the oscilloscope cannot acquire all the points for a complete record with a single trigger event. That condition occurs when the oscilloscope is limited to real time sampling and the time base is set to a value that exceeds the effective sample rate of the oscilloscope. The digitizing oscilloscope has two interpolation options: *linear* or *sin(x)/x interpolation*.

Linear interpolation calculates record points in a straight-line fit between the actual values acquired. Sin(x)/x computes record points in a curve fit between the actual values acquired. It assumes all the interpolated points fall in their appropriate point in time on that curve.

Intensity

Display brightness.

Knob

A rotary control.

Low

The value used as 0% in automated measurements (whenever high ref, mid ref, and low ref values are needed as in fall time and rise time measurements). May be calculated using either the min/max or the histogram method. With the min/max method (most useful for general waveforms), it is the minimum value found. With the histogram method (most useful for pulses), it refers to the most common value found below the mid point. See *Appendix D: Algorithms* for details.

Main menu

A group of related controls for a major oscilloscope function that the oscilloscope displays across the bottom of the screen.

Main menu buttons

Bezel buttons under the main menu display. They allow you to select items in the main menu.

Maximum

Amplitude (voltage) measurement of the maximum amplitude. Typically the most positive peak voltage.

Mean

Amplitude (voltage) measurement of the arithmetic mean over the entire waveform.

Minimum

Amplitude (voltage) measurement of the minimum amplitude. Typically the most negative peak voltage.

Negative duty cycle

A timing measurement representing the ratio of the negative pulse width to the signal period, expressed as a percentage.

Negative overshoot measurement

Amplitude (voltage) measurement.

$$NegativeOvershoot = \frac{Low - Min}{Amplitude} \times 100\%$$

Negative Sync

A highly standardized pulse that appears at the end of each horizontal line and frame in a video signal. The leading edge of the pulse is in the negative direction.

Negative width

A timing measurement of the distance (time) between two amplitude points—falling-edge *MidRef* (default 50%) and rising-edge *MidRef* (default 50%)—on a negative pulse.

Normal trigger mode

A mode on which the oscilloscope does not acquire a waveform record unless a valid trigger event occurs. It waits for a valid trigger event before acquiring waveform data.

NTSC

A video signal standard used in United States and Canada. It has a line rate of 525 lines and a field rate of 60 Hz.

Oscilloscope
An instrument for making a graph of two factors. These are typically voltage versus time.

PAL
A general video signal standard used in Europe and many parts of the world. It typically has a line rate of 625 lines and a field rate of 50 Hz.

Peak Detect acquisition mode
A mode in which the oscilloscope saves the minimum and maximum samples over two adjacent acquisition intervals. For many glitch-free signals, that mode is indistinguishable from the sample mode. (Peak detect mode works with real-time, non-interpolation sampling only.)

Peak-to-Peak
Amplitude (voltage) measurement of the absolute difference between the maximum and minimum amplitude.

Period
A timing measurement of the time covered by one complete signal cycle. It is the reciprocal of frequency and is measured in seconds.

Pixel
A visible point on the display. The oscilloscope display is 640 pixels wide by 480 pixels high.

Pop-up Menu
A sub-menu of a main menu. Pop-up menus temporarily occupy part of the waveform display area and are used to present additional choices associated with the main menu selection. You can cycle through the options in a pop-up menu by repeatedly pressing the main menu button underneath the pop-up.

Positive duty cycle
A timing measurement of the ratio of the positive pulse width to the signal period, expressed as a percentage.

Positive overshoot
Amplitude (voltage) measurement.

$$PositiveOvershoot = \frac{Max - High}{Amplitude} \times 100\%$$

Positive Sync
A highly standardized pulse that appears at the beginning of each horizontal line and frame in a video signal. The leading edge of the pulse is in the positive direction.

Positive width
A timing measurement of the distance (time) between two amplitude points—rising-edge *MidRef* (default 50%) and falling-edge *MidRef* (default 50%)—on a positive pulse.

Posttrigger
The specified portion of the waveform record that contains data acquired after the trigger event.

Pretrigger
The specified portion of the waveform record that contains data acquired before the trigger event.

Probe
An oscilloscope input device.

Probe compensation
Adjustment that improves low-frequency response of a probe.

Real-time sampling
A sampling mode where the digitizing oscilloscope samples fast enough to completely fill a waveform record from a single trigger event. Use real-time sampling to capture single-shot or transient events.

Record length
The specified number of samples in a waveform.

Reference memory
Memory in a oscilloscope used to store waveforms or settings. You can use that waveform data later for processing. The digitizing oscilloscope saves the data even when the oscilloscope is turned off or unplugged.

Rise time
The time it takes for a leading edge of a pulse to rise from a *LowRef* value (typically 10%) to a *HighRef* value (typically 90%) of its amplitude.

RMS
Amplitude (voltage) measurement of the true Root Mean Square voltage.

Sample acquisition mode
The oscilloscope creates a record point by saving the first sample during each acquisition interval. That is the default mode of the acquisition.

Sample interval
The time interval between successive samples in a time base.

Sampling
The process of converting a portion of the input signal to digital form for display and processing. Two general methods of sampling are: *real-time sampling* and *equivalent-time sampling.*

SECAM
A general video signal standard used in France and the USSR. It typically has a line rate of 625 lines and a field rate of 50 Hz.

Selected waveform
The waveform on which all measurements are performed, and which is affected by vertical position and scale adjustments. The light next to one of the channel selector buttons indicates the current selected waveform.

Side menu
Menu that appears to the right of the display. These selections expand on main menu selections.

Side menu buttons
Bezel buttons to the right of the side menu display. They allow you to select items in the side menu.

Slope
The direction at a point on a waveform. You can calculate the direction by computing the sign of the ratio of change in the vertical quantity (Y) to the change in the horizontal quantity. The two values are rising and falling.

Time base
The set of parameters that let you define the time and horizontal axis attributes of a waveform record. The time base determines when and how long to acquire record points.

Toggle button
A button that changes which of the two cursors is active.

Trigger
An event that marks time zero in the waveform record. It results in acquisition and display of the waveform.

Trigger level
The vertical level the trigger signal must cross to generate a trigger (on edge mode).

Vertical bar cursors
The two vertical bars you position to measure the time parameter of a waveform record. The oscilloscope displays the value of the active (moveable) cursor with respect to trigger and the time value between the bars.

Video Trigger
Triggering occurs when the oscilloscope detects a sync pulse with the specified polarity in field one, field two, or alternately in field one and two.

Waveform
The shape or form (visible representation) of a signal.

Waveform interval
The time interval between record points as displayed.

XY format
A display format that compares the voltage level of two waveform records point by point. It is useful for studying phase relationships between two waveforms.

YT format
The conventional oscilloscope display format. It shows the voltage of a waveform record (on the vertical axis) as it varies over time (on the horizontal axis).

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